PNNL-14301, Rev. 2

Pacific Northwest National Laboratory
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Monitoring Plan for RCRA Groundwater Assessment at the 216-U-12 Crib

B. A. Williams
C. J. Chou

September 2005

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The 216-U-12 crib, located in the 200 West Area of the Hanford Site, is a regulated unit under the *Resource Conservation and Recovery Act* (RCRA). The treatment, storage, and/or disposal (TSD) unit, active until February 1988, primarily received process condensate from the 224 Building (also known as the UO_3 Plant), which has impacted the unconfined aquifer. This document contains a revised and updated monitoring plan for RCRA interim status groundwater assessment, site hydrogeology, and a conceptual model of the RCRA TSD unit. Please note that source, special nuclear and by-product materials, as defined in the *Atomic Energy Act of 1954* (AEA), are regulated at U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. These materials are not subject to regulation by the state of Washington. All information contained herein and related to, or describing AEA-regulated materials and processes in any manner, may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. DOE asserts that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

The 216-U-12 crib has been monitored under a RCRA interim status groundwater assessment monitoring program since the first quarter of 1993 (Williams and Chou 1993). Specific conductance in downgradient wells exceeded the critical mean value and triggered the assessment. The high specific conductance is attributed to elevated nitrate, which exceeds the drinking water standard in groundwater. Results of a Phase I and Phase II RCRA assessment indicated that the TSD unit was the source of the elevated nitrate and the non-RCRA constituent technetium-99 (Williams and Chou 1997) and interim status assessment monitoring must continue because, under existing conditions, downward migration and lateral spreading of these waste components from the vadose zone (and continued elevated specific conductance in downgradient wells) is still occurring.

Monitoring under interim status assessment is expected to continue until the 216-U-12 crib is incorporated as a chapter into the Hanford Facility RCRA Permit or administratively closed as proposed to the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) by DOE.[1] The objective of the ongoing RCRA interim status assessment (Part I) focuses on (1) continued groundwater monitoring to determine whether the flux of dangerous waste constituents (e.g., chromium) out of the vadose zone into the groundwater is increasing, staying the same, or decreasing, and (2) monitoring the known contaminant (i.e., nitrate).

The groundwater beneath the 216-U-12 crib is located within the CERCLA 200-UP-1 Groundwater Operable Unit and the crib is included as part of the 200-UW-1 Source Operable Unit. A portion of the 200-UW-1 Source Operable Unit (the U Plant Area waste sites) is being closed under an accelerated schedule in accordance with a planned focused feasibility study (FFS) (DOE 2003a) and proposed plan (PP) (DOE 2003b). This process will integrate closure of the 216-U-12 crib as part of the FFS and PP,

[1] Letter from KA Klein (DOE, Richland Operations Office) to N Ceto (EPA) and MA Wilson (Ecology) dated May 13, 2005: *Administrative Closure of the 216-U-12 Crib.*

which is consistent with the *200 Areas Remedial Investigation/Feasibility Study Implementation Plan-Environmental Restoration Program* (DOE 1999). As part of this integration with CERCLA, the site-specific waste constituent nitrate will be monitored to evaluate the contribution of nitrate from the 216-U-12 crib into the regional nitrate plume. Post-closure groundwater monitoring will be integrated with the 200-UP-1 Operable Unit groundwater monitoring plan. In accordance with the proposed plan for the U Plant closure area waste sites (DOE 2003b), remediation of contaminated groundwater beneath these U Plant waste sites will continue to be addressed under the 200-UP-1 Groundwater Operable Unit.

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Introduction

This plan provides a revised and updated *Resource Conservation and Recovery Act* (RCRA) interim status groundwater assessment monitoring program for the 216-U-12 crib and provides the updated site hydrogeology and the facility conceptual model.

The U.S. Department of Energy (DOE) has proposed to Washington State Department of Ecology that the 216-U-12 crib be administratively closed per remarks in Klein (2005).[1] The facility will remain in interim status assessment monitoring as detailed in this plan until administrative closure is approved or otherwise dispositioned.

Please note that source, special nuclear and by-product materials, as defined in the *Atomic Energy Act of 1954* (AEA), are regulated at DOE facilities exclusively by DOE acting pursuant to its AEA authority. These materials are not subject to regulation by the State of Washington. All information contained herein and related to, or describing AEA-regulated materials and processes in any manner, may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. DOE asserts that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

Description of 216-U-12 Crib

The 216-U-12 crib was built in 1960 to replace the 216-U-8 crib when it showed signs of potential cave-in. The 216-U-12 crib was operational until February 1, 1988, when the pipeline was cut and capped. The retired 216-U-12 crib was replaced by the 216-U-17 crib, which operated from 1988 to 1994. Information about the 216-U-12 crib and its underlying geology and hydrogeology, including a conceptual model of effluent migration through the vadose zone has been provided in the original groundwater monitoring plan by Jensen et al. (1990) and is revised and updated in Part II of this plan.

The crib is located downgradient of several other liquid waste disposal cribs in the 200 West Area of the Hanford Site (Figure 1). These cribs received large volumes of liquid effluent containing radioactive and hazardous waste at various times during the operational history of the U and S Plants. Details of all the facilities are provided in the Waste Information Data System (WIDS) database, managed by Fluor Hanford, Inc.

[1] Letter from KA Klein (DOE, Richland Operations Office) to N Ceto (EPA) and MA Wilson (Ecology) dated May 13, 2005: *Administrative Closure of the 216-U-12 Crib.*

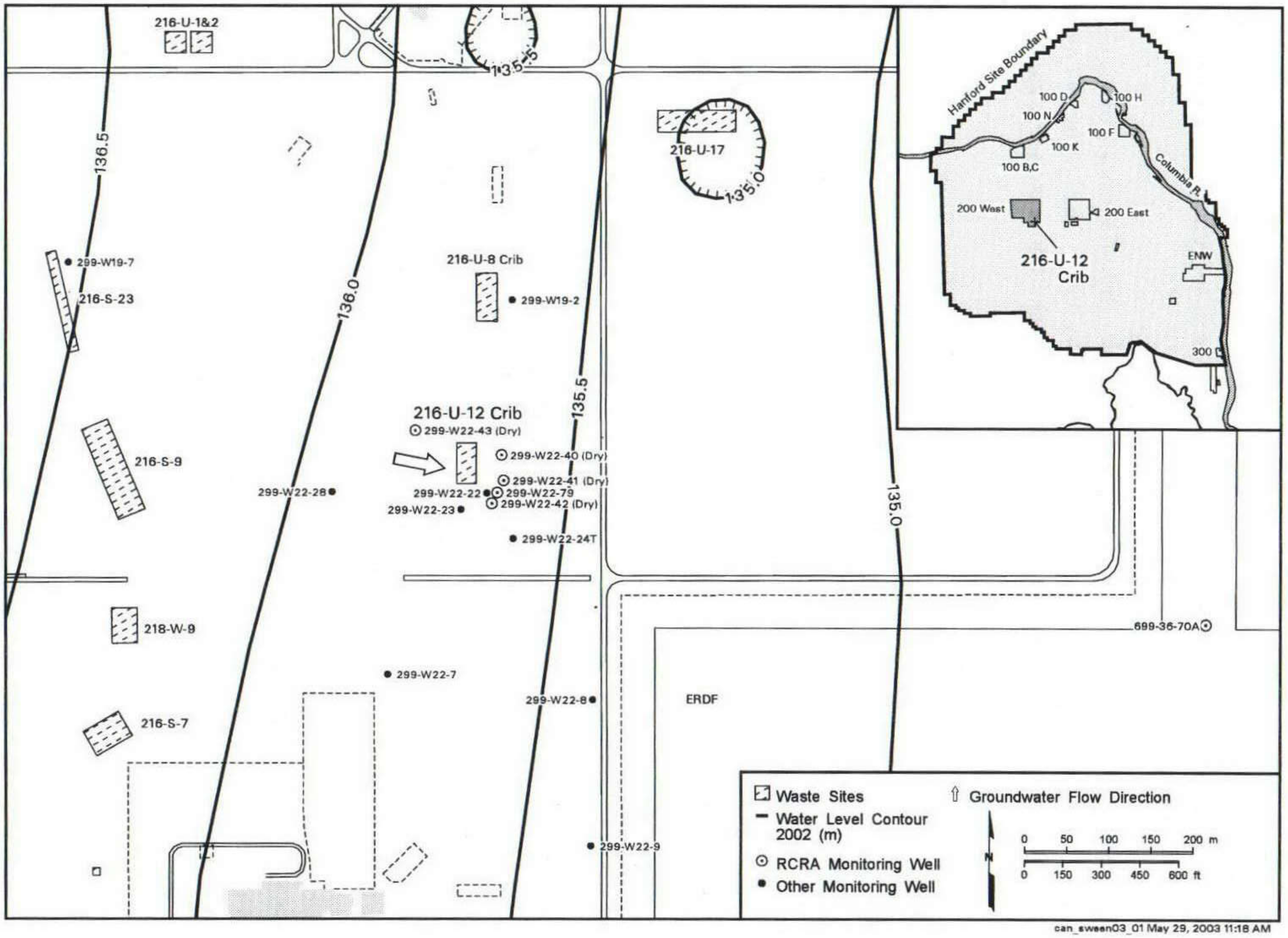

Figure 1. Location of 216-U-12 Crib on the Hanford Site, Washington

The 216-U-12 crib was a liquid waste-disposal unit composed of an unlined, gravel bottomed, percolation crib, 3 x 30 m (10 x 100 ft), 4.6 m (15 ft) deep. The gravel bottom crib has a plastic barrier cover and is backfilled with the original excavated sediment. Effluent was transferred to the crib via a vitrified clay pipe, and spread along a vitreous distributor pipe which is buried in the gravel. The crib was used to dispose (neutralize) corrosive waste primarily composed of process condensate from the 224-U Building (UO_3 Plant).

The crib received liquid waste, as described in WIDS, from 1960 through 1972 when the crib was deactivated. The crib was reactivated in November 1981 and received primarily the UO_3 Plant process condensate until it was permanently retired in February 1988. A yearly average of over 1.02×10^7 L/yr (2.7×10^6 gal/yr) of effluent was disposed to the crib from 1960 through 1972 (Maxfield 1979). Total volume disposed to the 216-U-12 crib exceeded 1.33×10^8 L (3.5×10^7 gal) from 1960 through 1972. Effluent volumes discharged to the 216-U-12 crib during its operational life are shown in Figure 2. Collectively, the effluent received over its entire life was nitric acid waste due to the UO_3 Plant process condensate and low-level radioactive waste known to have included plutonium, ruthenium, cesium-137, strontium-90, and uranium. More detailed information about the waste characteristics is available in the assessment results report by Williams and Chou (1993).

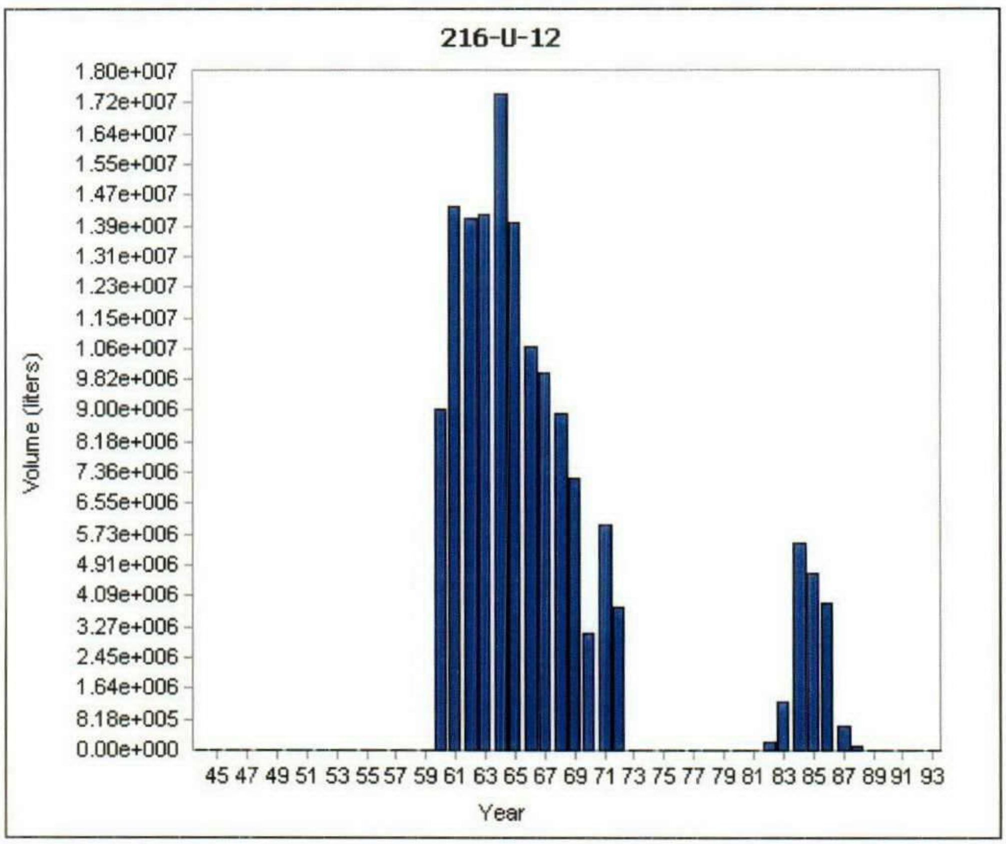

Figure 2. Effluent Volume Discharged to the 216-U-12 Crib

History of RCRA Monitoring at 216-U-12 Crib

The initial RCRA groundwater monitoring plan (Jensen et al. 1990) presented the groundwater monitoring program to determine the crib's impact on the quality of groundwater in the uppermost aquifer beneath the site. A groundwater monitoring well network was established in 1990 and monitoring began in 1991. This initial network consisted of one upgradient and three downgradient point-of-compliance wells (Figure 3). The wells were screened in the upper 6 m (20 ft) of the uppermost aquifer.

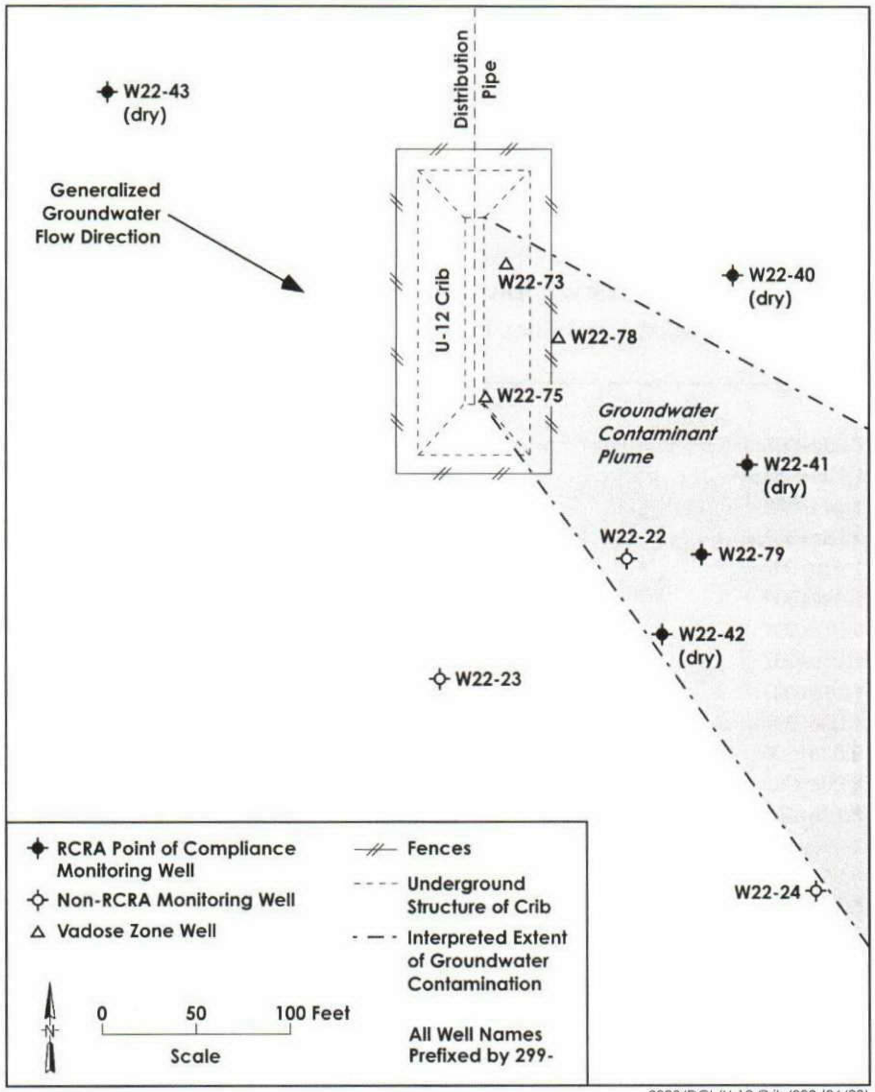

Figure 3. Initial RCRA Groundwater Monitoring Network for the 216-U-12 Crib

In accordance with RCRA interim status regulations 40 CFR 265.92 as referenced by WAC 173-303-400(3), initial background levels for the contaminant indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halogens) were established using groundwater samples collected between September 1991 and June 1992. The background (upgradient) well was 299-W22-43. Specific conductance data collected during September 1992 from downgradient wells 299-W22-41 and 299-W22-42 showed a statistically significant increase over background values [40 CFR 265.93(c)(2)]. Data obtained in subsequent quarters corroborated these findings.

Based on these results, a RCRA interim-status groundwater quality assessment monitoring program was implemented for the crib in January 1993. Since then, the groundwater monitoring well network at the crib has been sampled quarterly in accordance with the groundwater quality assessment plan (Williams and Chou 1993) [40 CFR 265.94(d)(4)]. The assessment plan was developed to determine whether the 216-U-12 crib is the source of the observed contamination (i.e., Phase I) and if so, to determine the concentration, rate, and extent of migration of the contaminant plumes (Phase II).

The groundwater monitoring network was expanded in 1993 by adding two existing older wells (non-RCRA-compliant) to the network. Two wells were added to the network: upgradient well 299-W22-23 for source identification purposes and downgradient well 299-W22-22 for source delineation. This expansion was necessary to assist in determining whether the 216-U-12 crib was the source or if one of several upgradient disposal facilities could be the source of the detected contaminants.

In 1995, well 699-36-70A was added downgradient near the Environmental Remediation Disposal Facility (ERDF) to support the Phase II assessment to determine the rate and extent of the contamination (Figure 1). Well 699-36-70A was drilled through the entire uppermost unconfined aquifer and through the Ringold Unit (lower mud unit) confining interval to characterize aquifer chemistry and hydrogeologic conditions downgradient of the 216-U-12 crib. This data (Williams 1995) has been used to delineate the vertical distribution of certain contaminants (nitrate, carbon tetrachloride, and technetium-99) in the upper aquifer. Results from this well indicate that nitrate, the contaminant source from the 216-U-12 crib, is dispersed throughout the upper aquifer and concentrations decrease with depth. A 10.7-m- (35-ft-) long screen was installed to monitor the top of the aquifer consistent with recently constructed monitoring wells in the area. In 1995, wells 299-W22-22 and 299-W22-23 were dropped from the network because of excessive turbidity problems and they were going dry.

In 1997, results of RCRA Groundwater Quality Assessment Program at the 216-U-12 crib (Williams and Chou 1997) indicated that the 216-U-12 crib is the source of elevated specific conductance (Figure 4), including elevated nitrate, and technetium-99. Elevated levels of iodine-129 and tritium are from upgradient sources caused by past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the REDOX Plant located near the south end of the 200 West Area. In addition, elevated levels of carbon tetrachloride are most likely from various Plutonium Finishing Plant waste disposal sites located northwest of the 216-U-12 crib.

Even though the 216-U-12 crib has been isolated since 1988, elevated nitrate and technetium-99 are still present in the groundwater, but concentrations are declining over time (Figures 5 and 6), indicating there is still vadose drainage that is contaminating the aquifer.

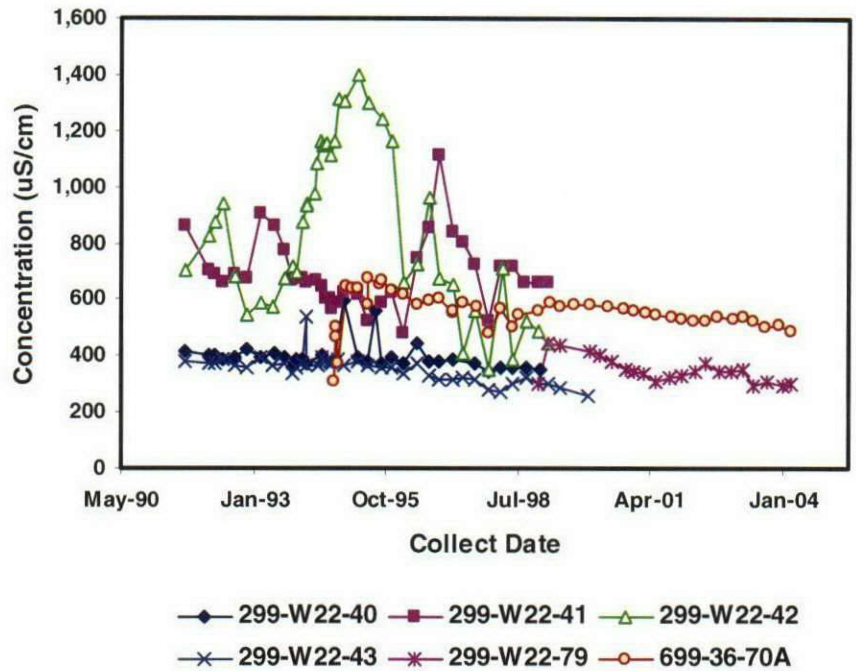

Figure 4. Specific Conductance versus Time for Wells at the 216-U-12 Crib

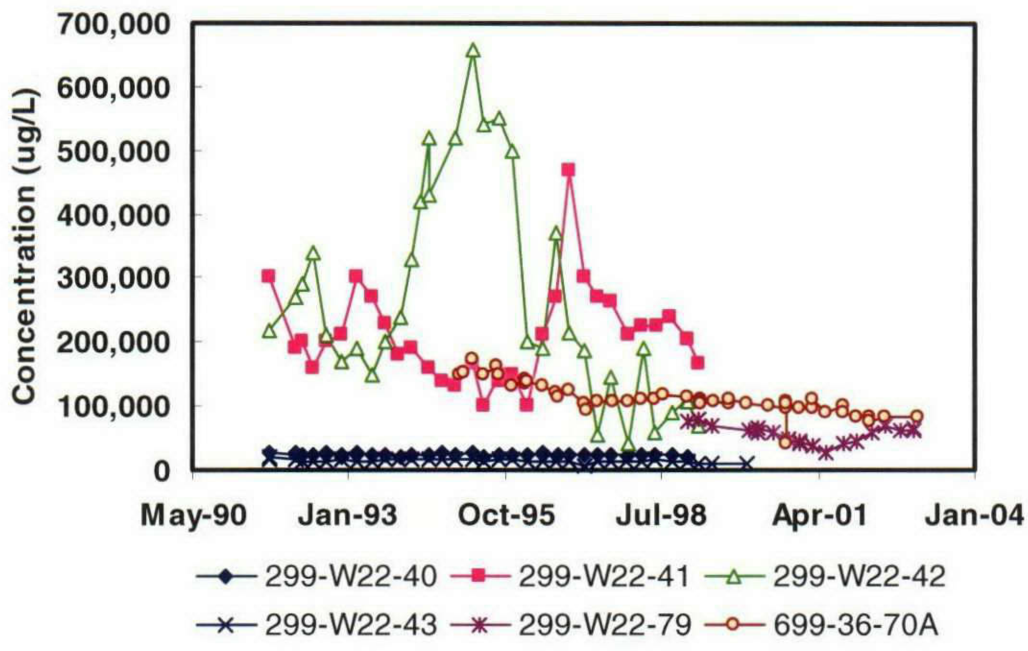

Figure 5. Nitrate Concentrations versus Time Plot for the 216-U-12 Crib

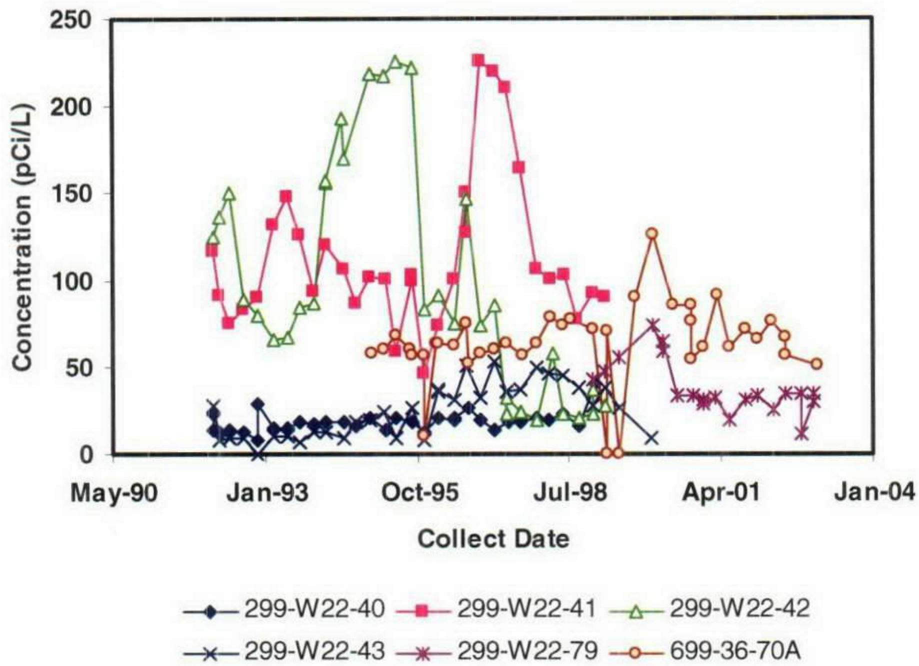

Figure 6. Technetium-99 Concentrations versus Time Plot for the 216-U-12 Crib

In 1998, well 299-W22-79 was installed as a replacement well between downgradient wells 299-W22-41 and 299-W22-42 because they were going dry (Figure 5). By 2002, all four of the original detection monitoring wells (299-W22-40, 299-W22-41, 299-W22-42, and 299-W22-43) had gone dry due to declining water levels across the 200 West Area. The current well network for RCRA groundwater assessment monitoring consists of just two wells, 299-W22-79 and 699-36-70A, both downgradient of the 216-U-12 crib. The Washington State Department of Ecology (Ecology) and U.S. Department of Energy (DOE) annually negotiate and prioritize installation of new monitoring wells. These agreements are documented in TPA Milestone M-24-00 change forms.[3]

Table 1 summarizes groundwater monitoring results for the 216-U-12 crib from 1992 until present based on selected constituents of interest identified in Reidel et al. (1993) and in Williams and Chou (1997) except for acetone and mercury. Mercury was not analyzed in samples from the four original network wells (299-W22-40, 299-W22-41, 299-W22-42, and 299-W22-43) after September 1993 and was not analyzed in samples from well 699-36-70A after March 1996. Mercury was essentially not detected in all wells. Acetone, a common lab contaminant, was not detected except for occasional hits in well 699-36-70A (5 detects out of a total 16 analyses). Currently, nitrate concentrations in the two remaining network (downgradient) wells 299-W22-79 (61,100 µg/L, December 2002) and 699-36-70A (83,700 µg/L, January 2003) exceed the maximum contaminant level of 45,000 µg/L. Trend plots for these selected constituents are available in Appendix C.

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[3] Email from RD Morrison (Fluor Hanford, Inc., Richland, Washington) to Distribution, dated October 12, 2004: *Tri-Party Agreement Change Form M-24-04-01 Approved.*

Table 1. Summary of Groundwater Monitoring Results at the 216-U-12 Crib

Well[a]	Time Period	Number of Samples				Detected Analyses		
		n	GT	LT	Excl.	Max.	Min.	Ave.
Nitrate (µg/L)								
299-W22-43 (dry)	2/92 – 9/93	33	33	0	0	18,000	8,190	14,600
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	28,300	19,700	24,600
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	469,000	99,000	209,000
299-W22-42 (dry)	2/92 – 3/99	34	33	0	1	660,000	41,400	258,400
299-W22-79	12/98 – 12/02	20	20	0	0	79,700	27,900	57,000
699-36-70A	9/94 – 1/03	53	47	0	6	172,000	76,700	113,100
Fluoride (µg/L)								
299-W22-43 (dry)	2/92 – 1/00	33	33	0	0	1,000	393	620
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	900	460	614
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	1,100	460	686
299-W22-42 (dry)	2/92 – 3/99	34	32	0	2	1,200	414	686
299-W22-79	12/98 – 12/02	20	20	0	0	650	530	584
699-36-70A	9/94 – 1/03	42	35	6	1	1,000	280	525
Sulfate (µg/L)								
299-W22-43 (dry)	2/92 – 1/00	33	33	0	0	31,000	18,400	25,300
299-W22-40 (dry)	2/92 – 1/99	32	31	0	1	33,000	27,600	30,750
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	37,000	22,800	30,000
299-W22-42 (dry)	2/92 – 3/99	34	33	0	1	48,500	25,300	30,900
299-W22-79	12/98 – 12/02	20	20	0	0	28,800	16,400	20,000
699-36-70A	9/94 – 1/03	42	41	1	0	37,600	23,000	33,500
Uranium (µg/L)								
299-W22-43 (dry)	2/92 – 9/93	8	8	0	0	4.1	2.4	3.1
299-W22-40 (dry)	2/92 – 3/94	11	11	0	0	4.1	1.3	3.3
299-W22-41 (dry)	2/92 – 9/93	8	8	0	0	2.5	1.8	2.1
299-W22-42 (dry)	2/92 – 6/98	15	15	0	0	4.1	2.4	3.2
299-W22-79		---	---	---	---	---	---	---
699-36-70A	9/94 – 1/03	21	19	1	1	3.9	0.6	2.9
Filtered Chromium (µg/L)								
299-W22-43 (dry)	2/92 – 1/00	28	11	16	1	25	3.4	7.5
299-W22-40 (dry)	2/92 – 3/98	28	16	11	1	24	2.8	10.0
299-W22-41 (dry)	2/92 – 3/99	28	13	15	1	18	2.7	7.1
299-W22-42 (dry)	2/92 – 3/99	28	14	13	2	31	4.2	10.9
299-W22-79	12/98 – 12/02	7	6	1	0	10.6	1.7	4.8
699-36-70A	9/94 – 1/03	39	23	16	0	10	1.5	5.4
Filtered Arsenic (µg/L)								
299-W22-43 (dry)	2/92 – 9/93	8	3	5	0	5.5	3.6	4.4
299-W22-40 (dry)	2/92 – 3/95	11	6	5	0	5.8	4.3	5.2
299-W22-41 (dry)	2/92 – 3/95	9	3	6	0	5.1	2.9	3.9
299-W22-42 (dry)	2/92 – 9/93	8	2	6	0	3.2	2.3	2.8
299-W22-79		---	---	---	---	---	---	---
699-36-70A	1/95 – 3/02	17	14	3	0	5.2	1.2	3.1

Table 1. (contd)

Well[(a)]	Time Period	Number of Samples				Detected Analyses		
		n	GT	LT	Excl.	Max.	Min.	Ave.
Potassium (μg/L)								
299-W22-43 (dry)	2/92 – 1/00	28	26	1	1	10,000	2,200	4,070
299-W22-40 (dry)	2/92 – 3/98	28	27	0	1	5,520	2,800	4,250
299-W22-41 (dry)	2/92 – 3/99	28	27	0	1	5,000	2,330	4,130
299-W22-42 (dry)	2/92 – 3/99	28	27	0	1	8.620	3,730	5,720
299-W22-79	12/98 – 12/02	7	7	0	0	4,800	2,690	3,670
699-36-70A	9/94 – 1/03	29	29	0	6	10,000	4,800	6,030
Technetium-99 (pCi/L)								
299-W22-43 (dry)	2/92 – 1/00	33	31	2	0	53.2	6.67	26.06
299-W22-40 (dry)	2/92 – 1/99	32	31	0	1	40.7	8.21	18.41
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	226	45.78	113.39
299-W22-42 (dry)	2/92 – 3/99	33	33	0	0	226	19.4	99.81
299-W22-79	12/98 – 12/02	20	20	0	0	73.9	12.1	37.87
699-36-70A	9/94 – 1/03	44	36	0	8	126	10.92	67.06
Strontium-90 (pCi/L)								
299-W22-43 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-40 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-41 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-42 (dry)	·12/93 – 12/94	6	0	6	0	ND	ND	ND
299-W22-79		---	---	---	---	---	---	---
699-36-70A	9/94 – 3/96	8	0	8	0	ND	ND	ND
Tritium (pCi/L)[(b)]								
299-W22-43 (dry)	2/92 – 1/00	33	26	7	0	2,690	296	1,500
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	4,370	1,030	2,130
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	15,400	463	3,040
299-W22-42 (dry)	2/92 – 3/99	33	32	0	1	54,500	9,120	23,940
299-W22-79	12/98 – 12/02	14	14	0	0	22,300	5,200	14,430
699-36-70A	9/94 – 1/03	37	32	0	5	388,000	53,700	150,800
Iodine-129 (pCi/L)[(b)]								
299-W22-43 (dry)	3/93 – 1/00	21	4	17	0	6.6	0	1.65
299-W22-40 (dry)	3/93 – 3/98	19	4	15	0	1.94	0.22	0.89
299-W22-41 (dry)	3/93 – 3/99	21	6	15	0	0.66	0	0.29
299-W22-42 (dry)	3/93 – 3/99	21	20	1	0	12.3	2.0	7.09
299-W22-79	12/98 – 12/02	9	0	9	0	ND	ND	ND
699-36-70A	1/95 – 1/03	35	32	2	1	38.8	6.38	15.24
Carbon Tetrachloride (μg/L)[(b)]								
299-W22-43 (dry)	12/92 – 9/94	12	11	1	0	10	3.7	6.9
299-W22-40 (dry)	2/92 – 8/96	16	16	0	0	10	6.7	8.1
299-W22-41 (dry)	2/92 – 9/94	12	12	0	0	8.1	4.7	6.6
299-W22-42 (dry)	2/92 – 12/94	14	14	0	0	6.8	3.1	5.3
299-W22-79	1/95 – 3/96	2	2	0	0	4	3	3.5
699-36-70A	1/95 – 1/03	17	16	1	0	11	3	7.3

(a) Bold and italic denotes upgradient well.
(b) Sources are from upgradient past disposal sites.
n = Number of samples; Excl. = excluded; GT = greater than; LT = less than; Max = maximum; Min = minimum; Ave = average; ND = not detected; --- = no data.

In 2002, the DOE initiated the Cleanup, Challenges, and Constraints Team (C3T) to develop, streamline, and integrate the groundwater programs managed under three separate regulatory acts (CERCLA, RCRA, and the *Atomic Energy Act of 1954*) into one. As part of this effort, the data quality objective (DQO) process (Byrnes and Williams 2003) was used to identify and integrate wells needed across the 200 Area Plateau. In accordance with this DQO, additional wells are justified at the 216-U-12 crib, i.e., at least two new wells could be required: one upgradient and one downgradient.

Integration of RCRA and CERCLA Closure Activities

The 216-U-12 crib is proposed to be administratively closed and removed from the list of TSDs contained in Appendix B of the TPA and will be closed as a RCRA past-practice site under the 200-UW-1 Operable Unit. Closure for the 216-U-12 crib will be fulfilled by the CERCLA process for the 200-UW-1 and 200-UP-1 Operable Units. Any remedial actions relating to groundwater that may be required for the 200-UP-1 Groundwater Operable Unit, which includes contaminants sourced from the 216-U-12 crib, will be conducted under the integrated TPA process (Byrnes and Robinson 2003). The groundwater monitoring network for the 200-UP-1 Groundwater Operable Unit includes select wells from the 216-U-12 crib RCRA network as defined in this plan and in Byrnes and Williams (2003).

Because the 216-U-12 crib is within the 200-UW-1 Operable Unit, remediation and closure of the 216-U-12 crib will be integrated with closure of the U Plant Area waste sites. The 200-UP-1 Groundwater Operable Unit is responsible for addressing contaminants within the groundwater beneath the 200-UW-1 Operable Unit. This plan is intended to serve as a transition to a monitoring approach that will be defined under the 200-UW-1 Operable Unit.

PART I

Interim-Status Groundwater Quality Assessment Plan for the 216-U-12 Crib

This part describes a revised and updated *Resource Conservation and Recovery Act* (RCRA) interim-status groundwater quality assessment monitoring program for the 216-U-12 crib. This revised interim-status program will fulfill RCRA groundwater monitoring requirements at the 216-U-12 crib until administrative closure of the facility is approved (described in the Introduction) or the facility is otherwise dispositioned. This part contains the sampling and analysis plan, including the monitoring constituents; sample frequencies; network design; sampling and analysis protocols; quality assurance; and data management, evaluation, and reporting. This plan replaces Williams and Chou (2003; PNNL-14301).

1.1 Objectives of RCRA Interim Status Assessment Monitoring

Results of the groundwater quality assessment monitoring activities conducted for the 216-U-12 crib (Williams and Chou 1997) indicate that the 216-U-12 crib is the source of the elevated nitrate and technetium-99 contamination observed in groundwater downgradient of the crib; the site must remain in interim-status groundwater assessment monitoring. However, in the interim remedial measures for the 200-UP-1 Groundwater Operable Unit, the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) determined that nitrate (and tritium) in groundwater will not be remediated until practical treatment options are available that will allow cost-effective removal (Swanson 1996). Furthermore, the Tri-Party Agreement (TPA) (Ecology et al. 1989) has assigned *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) as the program that will address the corrective action provisions of RCRA. Therefore, any future cleanup of contaminants in groundwater at the crib will be part of the CERCLA 200-UP-1 Groundwater Operable Unit investigation and subsequent remedial or corrective action decisions. Any soil remediation required at the 216-U-12 crib within the 200-UW-1 Source Operable Unit will be performed under the CERCLA U Plant focused feasibility study (FFS)/proposed plan (PP) waste site remediation documentation.

Based on the information presented in the paragraph above, the current objectives of interim status assessment monitoring for the 216-U-12 crib, rather than delineating the existing known plumes, include the following:

1. Continue groundwater monitoring to assess the migration of potential dangerous waste constituents out of the vadose zone into the groundwater.

2. Monitor the known contaminants until a near-term interim corrective action is defined.

3. Monitor under interim-status assessment until administrative closure is approved or the facility is otherwise dispositioned.

Closure of the 216-U-12 crib will be coordinated with and conducted under CERCLA per the U Plant waste sites FFS (DOE 2003a) and PP (DOE 2003b). RCRA groundwater monitoring objectives will remain the same from now until administrative closure of the facility is approved.

1.2 Sampling and Analysis Plan

This section describes the monitoring program for RCRA interim status groundwater assessment for the 216-U-12 crib, which is designed to assess facility impacts to groundwater as described in the Introduction.

1.2.1 Groundwater Monitoring Well Network

The requirements, objectives, and network design for RCRA groundwater monitoring at the 216-U-12 crib and for the 200-UP-1 Groundwater Operable Unit regional network have been defined in Byrnes and Williams (2003). Based on the objectives defined in the data quality objective (DQO), the existing interim status 216-U-12 crib network will be modified to increase the number of monitoring wells from the existing two wells to four wells. The 216-U-12 crib network currently consists of two RCRA compliant (WAC 173-160) wells, 299-W22-79 and 699-36-70A (Figure 1.1). These two wells monitor the top of the unconfined aquifer, which is believed to be where most contaminants travel in groundwater. The initial four network wells have gone dry (Williams and Chou 1993). Well deepening, as proposed in the DQO, will not be necessary because one new CERCLA well is being installed near the existing dry downgradient well that was to be deepened. In addition, one existing upgradient well will be added to the network to provide upgradient coverage at the 216-U-12 crib. Installation of new wells is being prioritized annually via TPA Milestone M-24-57. Figure 1.1 provides the location of the four wells proposed for this network (Table 1.1). Appendix A provides well as-built information about the proposed network wells for continuing interim status assessment groundwater monitoring at the 216-U-12 crib. This 216-U-12 crib groundwater monitoring network supports groundwater monitoring objectives for the regional 200-UP-1 groundwater monitoring network (Byrnes and Williams 2003).

1.2.2 Constituent List and Sampling Frequency

Samples will continue to be analyzed quarterly as required by RCRA regulations. Water levels will also be collected at the same time the wells are sampled. Additional constituents will be analyzed annually, as necessary, to assist in data evaluation. Based on waste stream characteristics, selected constituents for this site are: alkalinity, anions (specific for nitrate), metals (specific for arsenic and chromium), pH, specific conductance, technetium-99, temperature, total dissolved solids, and turbidity. Technetium-99 is a non-RCRA constituent that is being tracked to assist in determining groundwater flow rate and direction beneath the crib. Table 1.2 provides the list of wells, constituents, and frequency of sampling and water-level monitoring for the network.

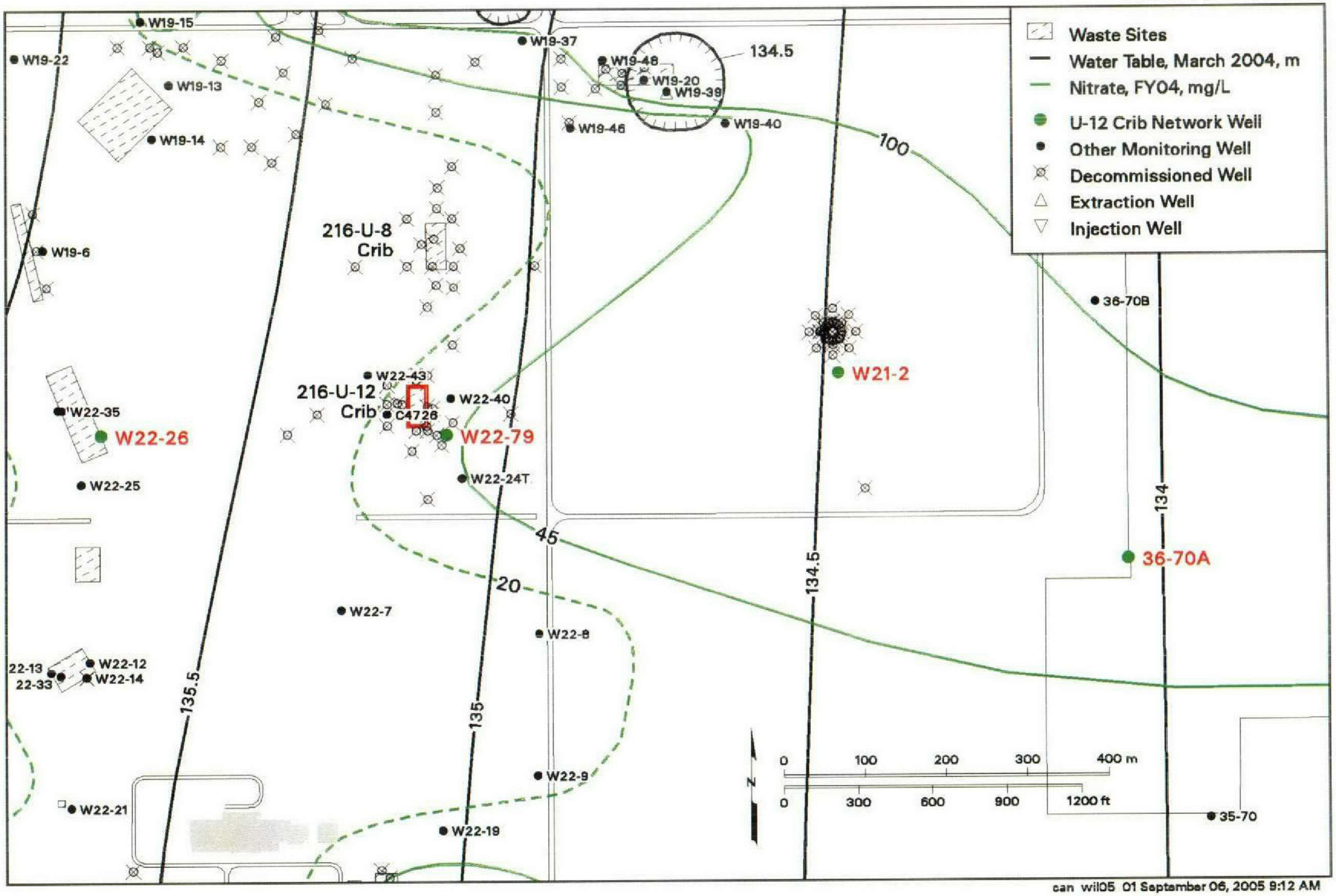

Figure 1.1. RCRA Interim-Status Assessment Monitoring Network for the 216-U-12 Crib

Table 1.1. 216-U-12 Crib Interim Status Groundwater Monitoring Network

Well	Well Standard	Unit Monitored	Comment	Other Users
299-W22-26	Screening well	Top of unconfined	Upgradient well location	CERCLA
299-W22-79	WAC 173-160	Top of unconfined	In current network	CERCLA
699-36-70A	WAC 173-160	Top of unconfined	In current network	CERCLA
299-W21-2	WAC 173-160	Top of unconfined	Installed in CY04 for 200 UP-1 monitoring	CERCLA
Italics = Wells to be added to network based on Tri-Party Agreement Milestone M-24-57.				

Table 1.2. Well Constituents and Frequency of Sampling at the 216-U-12 Crib

	Constituents Required Under This Plan			Constituents Supporting Interpretation															
Well Number	Arsenic	Chromium (total; filt.)	Nitrate	Alkalinity	Chloride	Nitrate	Sulfate	Calcium (filtered)	Potassium (filtered)	Magnesium (filtered)	Sodium (filtered)	Tc-99[a]	TDS	pH	Specific conductance	Temperature	Turbidity	Water Levels[b]
299-W22-26	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
299-W22-79	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
699-36-70A	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
299-W21-2	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q

(a) Not regulated under RCRA; co-contaminant analyzed to help determine groundwater flow rate and direction and to support CERCLA and AEA monitoring.
(b) Measured before purging well for sampling.
A = annually; Q = quarterly.

1.2.3 Sampling and Analysis Protocol

RCRA groundwater monitoring for the 216-U-12 crib is part of the groundwater project and follows the project's quality assurance plan. Groundwater monitoring for the 216-U-12 crib will follow the requirements of the most recent revision of the quality assurance project plan; this monitoring plan need not be revised to cite future revisions of the quality assurance plan.

Project staff schedule sampling and initiate paperwork. The project uses subcontractors for sample collection, shipping, and analysis. Quality requirements for the subcontracted work are specified in statements of work or contracts.

The statement of work for sampling activities specifies that activities shall be in accordance with a quality assurance project plan that meets the requirements defined in *Requirements for Quality Assurance Project Plans,* EPA/240/B-01/003 (EPA QA/R-5), March 2001, as amended. Additional requirements are specified in the statement of work.

Groundwater project staff conduct laboratory audits and field surveillances to assess the quality of subcontracted work and initiate corrective action if needed.

1.2.3.1 Scheduling Groundwater Sampling

The groundwater project schedules well sampling. Many Hanford Site wells are sampled for multiple objectives and requirements, e.g., RCRA, CERCLA, *Atomic Energy Act of 1954* (AEA). Scheduling activities help manage the overlap, eliminating redundant sampling and meeting the needs of each sampling objective. Scheduling activities include the following:

- Each fiscal year, project scientists provide well lists, constituent lists, and sampling frequency. Each month, project scientists review the sampling schedule for the following month. Changes are requested via change request forms and approved by the sampling and analysis task lead and the monitoring project manager.

- Project staff track sampling and analysis through an electronic schedule database, stored on a server at Pacific Northwest National Laboratory (PNNL). Quality control samples also are managed through this database. A scheduling program generates unique sample numbers and a special user interface generates sample authorization forms, field services reports, groundwater sample reports, chain-of-custody forms, and sample container labels.

- Sampling and analysis staff verify that well name, sample numbers, bottle sizes, preservatives, etc. are indicated properly on the paperwork, which is transmitted to the sampling subcontractor. Staff complete a checklist to document that the paperwork was generated correctly.

- At each month's end, project staff use the schedule database to determine if any wells were not sampled as scheduled. If the wells or sampling pumps require maintenance, sampling is rescheduled following repair. If a well can no longer be sampled, it is cancelled, and the reason is recorded in the database. The U.S. Department of Energy (DOE) will notify Ecology if sampling is delayed past the end of the scheduled quarter or if a well cannot be sampled (see Section 1.3.1).

1.2.3.2 Chain of Custody

The sampling subcontractor uses chain-of-custody forms to document the integrity of groundwater samples from the time of collection through data reporting. The forms are generated during scheduling (see Section 1.2.3.1) and managed by the sampling subcontractor. Samplers enter required information on the forms, including the following:

- Sampling Authorization Form number
- Sampler's name(s)
- Method of shipment and destination
- Collection date and time
- Sample identification numbers
- Analysis methods
- Preservation methods.

When samples are transferred from one custodian to another (e.g., from sampler to shipper or shipper to analytical laboratory), the receiving custodian inspects the form and samples and note any deficiencies. Each transfer of custody is documented by the printed names and signatures of the custodian relinquishing the samples and the custodian receiving the samples, and the time and date of transfer.

1.2.3.3 Sample Collection

Groundwater samples are generally collected after three casing volumes of water have been purged from the well or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized, i.e., after two consecutive measurements are within 0.2 units pH, 0.2°C for temperature, 10% for specific conductance, and turbidity <5 nephelometric turbidity units (NTU). Pre-printed sample labels are applied to bottles in the field. For routine groundwater samples, preservatives are added to the collection bottles, if necessary, before their use in the field. Samples for metal analyses are filtered in the field with 0.45-micrometer, in-line, disposable filters. After sampling, pH, temperature, and specific conductance are measured again. Sample bottles are sealed with evidence tape and placed in a cooler with ice for shipping.

The samplers record the date, time, personnel, field measurements, and other pertinent information on a groundwater sample report form and complete the chain-of-custody form as described in Section 1.2.3.2.

1.2.3.4 Analytical Protocols

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are calibrated in the field using standard solutions prior to use. Each instrument is assigned a unique number that is tracked on field documentation and is calibrated and controlled. Additional calibration and use instructions are specified in the instrument user's manuals.

Laboratory analytical methods are specified in contracts with the laboratories, and are standard methods from *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods* (EPA/SW-846, 1986, as amended) or *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-79-020, 1983, as amended).

1.3 Quality Assurance

The groundwater project's quality assurance plan meets *EPA Requirements for Quality Assurance Project Plans*, EPA/240/B-01/003 (EPA QA/R-5), March 2001, as amended. A quality control plan is included in the groundwater project quality assurance plan, and quality control sampling requirements for subcontracted work are discussed in the statement of work.

The groundwater project's quality control program is designed to assess and enhance the reliability and validity of groundwater data. This is accomplished through evaluating the results of quality control samples, conducting audits, and validating groundwater data. This section describes the quality control program for the entire groundwater project, which includes the 216-U-12 crib.

The quality control practices of the groundwater project are based on guidance from the U.S. Environmental Protection Agency (EPA) as described in the *Tri-Party Agreement Action Plan*, Section 6.5. Accuracy, precision, and detection are the primary parameters used to assess data quality. Data for these parameters are obtained from two categories of quality control samples: those that provide checks on field and laboratory activities (field quality control) and those that monitor laboratory performance (laboratory quality control). Table 1.3 summarizes the types of samples in each category and the sample frequencies and characteristics evaluated.

1.3.1 Quality Control Criteria

Quality control data are evaluated based on established acceptance criteria for each quality control sample type. For field and method blanks, the acceptance limit is generally two times the instrument detection limit (metals), and method detection limit (other chemical parameters). However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, and phthalate esters, the limit is five times the method detection limit. Groundwater samples that are associated (i.e., collected on the same date and analyzed by the same method) with out-of-limit field blanks are flagged with a "Q" in the database to indicate a potential contamination problem.

Field duplicates must agree within 20%, as measured by the relative percent difference (RPD), to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit are evaluated. Unacceptable field duplicate results are also flagged with a "Q" in the database.

The acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are generally derived from historical data at the laboratories in accordance with *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods* (EPA/SW-846, 1986, as amended). Typical acceptance limits are within 25% of the expected values, although the limits

Table 1.3. Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
	Field Quality Control	
Full Trip Blank	Contamination from containers or transportation	1 per 20 well trips
Field Transfer Blank	Airborne contamination from the sampling site	1 each day volatile organic compound samples are collected
Equipment Blank	Contamination from non-dedicated sampling equipment	1 per 10 well trips or as needed[a]
Duplicate Samples	Reproducibility	1 per 20 well trips
	Laboratory Quality Control	
Method Blank	Laboratory contamination	1 per batch
Lab Duplicates	Laboratory reproducibility	Method/contract specific[b]
Matrix Spike	Matrix effects and laboratory accuracy	Method/contract specific[b]
Matrix Spike Duplicate	Laboratory reproducibility and accuracy	Method/contract specific[b]
Surrogates	Recovery/yield	Method/contract specific[b]
Laboratory Control Sample	Accuracy	1 per batch
Double Blind Standards	Accuracy and precision	Varies by constituent[c]

(a) When a new type of non-dedicated sampling equipment is used, an equipment blank should be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the equipment's decontamination procedure.
(b) If called for by the analytical method, duplicates, matrix spikes, and matrix spike duplicates are typically analyzed at a frequency of 1 per 20 samples. Surrogates are routinely included in every sample for most gas chromatographic methods.
(c) Double blind standards containing known concentrations of selected analytes are typically submitted in triplicate or quadruplicate on a quarterly, semi-annual, or annual basis.

may vary considerably with the method and analyte. Current values for laboratory duplicates, matrix spikes, and laboratory control samples are 20% RPD, 60%-140%, and 70%-130%, respectively. These values are subject to change if the contract is modified or replaced.

Table 1.4 lists the acceptable recovery limits for the double blind standards. These samples are prepared by spiking background well water with known concentrations of constituents of interest. Spiking concentrations range from the detection limit to the upper limit of concentration determined in groundwater on the Hanford Site. Double blind standard results that are outside the acceptance limits are investigated and appropriate actions are taken if necessary.

Holding time is the elapsed time period between sample collection and analysis. Exceeding recommended holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Recommended holding times depend on the analytical method, as specified in *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods* (EPA/SW-846,

Table 1.4. Recovery Limits for Double Blind Standards

Constituent	Frequency	Recovery Limits	Precision Limits (RSD)
Specific conductance	Quarterly	75%–125%	25%
Total organic carbon[a]	Quarterly	75%–125%	Varies with spiking compound
Total organic halides[b]	Quarterly	75%–125%	Varies with spiking compound
Cyanide	Quarterly	75%–125%	25%
Fluoride	Quarterly	75%–125%	25%
Nitrate	Quarterly	75%–125%	25%
Chromium	Annually	80%–120%	20%
Carbon tetrachloride	Quarterly	75%–125%	25%
Chloroform	Quarterly	75%–125%	25%
Trichloroethene	Quarterly	75%–125%	25%

(a) The spiking compound generally used for total organic carbon is potassium hydrogen phthalate. Other spiking compounds may also be used.
(b) Two sets of spikes for total organic halides will be used. The first should be prepared with 2,4,5-trichlorophenol. The second set will be spiked with a mixture of carbon tetrachloride, chloroform, and trichloroethene.
RSD = Relative standard deviation.

1986, as amended) or *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-79-020, 1983, as amended). Holding times are specified in laboratory contracts. Data associated with exceeded holding times are flagged with an "H" in the Hanford Environmental Information System (HEIS) database.

Additional quality control measures include laboratory audits and participation in nationally based performance evaluation studies. The contract laboratories participate in national studies such as the EPA-sanctioned Water Pollution and Water Supply Performance Evaluation studies. The groundwater project periodically audits the analytical laboratories to identify and solve quality problems or to prevent such problems. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies are presented in the annual groundwater monitoring report.

1.3.2 Groundwater Data Validation Process

The groundwater project's data validation process provides requirements and guidance for validation of groundwater data that are routinely collected as part of the groundwater project. Validation is a systematic process of reviewing data against a set of criteria to determine whether the data are acceptable for their intended use. This process applies to groundwater data that have been verified (see Section 1.4.1) and loaded into HEIS. The outcome of the activities described below is an electronic data set with suspect or erroneous data corrected or flagged. Groundwater monitoring project staff documents the validation process quarterly by signing a checklist, which is stored in the project file.

Responsibilities for data validation are divided among project staff. Each RCRA unit or geographic region is assigned to a project scientist, who is familiar with the hydrogeologic conditions of that site. The data validation process includes the following elements.

- **Generation of data reports**: Twice each month, data management staff provide tables of newly loaded data to project scientists for evaluation (biweekly reports). Also, after laboratory results from a reporting quarter have been loaded into HEIS, staff produce tables of water-level data and analytical data for wells sampled within that quarter (quarterly reports). The quarterly data reports include any data flags added during the quality control evaluation or as a result of prior data review.

- **Project scientist evaluation**: As soon as practical after receiving biweekly reports, project scientists review the data to identify changes in groundwater quality or potential data errors. Evaluation techniques include comparing key constituents to historical trends or spatial patterns. Other data checks may include comparison of general parameters to their specific counterparts (e.g., conductivity to ions) and calculation of charge balances. Project scientists request data reviews if appropriate (see Section 1.4.2). If necessary, the lab may be asked to check calculations or reanalyze the sample, or the well may be resampled. After receiving quarterly reports, project scientists review sampling summary tables to determine whether network wells were sampled and analyzed as scheduled. If not, they work with other project staff to resolve the problem. Project scientists also review quarterly reports of analytical and water-level data using the same techniques as for biweekly reports. Unlike the biweekly reports, the quarterly reports usually include a full data set (i.e., all the data from the wells sampled during the previous quarter have been received and loaded into HEIS).

- Staff report results of quality control evaluations informally to project staff, DOE, and Ecology each quarter. Results for each fiscal year are described in the annual groundwater monitoring report.

1.4 Data Management, Evaluation, and Reporting

This section describes how groundwater data are stored, retrieved, and interpreted.

1.4.1 Loading and Verifying Data

The contract laboratories report analytical results electronically and in hard copy. The electronic results are loaded into HEIS. Hard copy data reports and field records are considered to be the record copies and are stored at PNNL. Project staff perform an array of computer checks on the electronic file for formatting, allowed values, data flagging (qualifiers), and completeness. Verification of the hard copy results includes checks for (1) completeness, (2) notes on condition of samples upon receipt by the laboratory, (3) notes on problems that arose during the analysis of the samples, and (4) correct reporting of results. If data are incomplete or deficient, staff work with the laboratory to get the problems corrected. Notes on condition of samples or problems during analysis may be used to support data reviews (see Section 1.4.2).

Field data such as specific conductance, pH, temperature, turbidity, and depth-to-water are recorded on field records. Data management staff enter these into HEIS manually through data-entry screens, verify each value against the hard copy, and initial each value on the hard copy.

1.4.2 Data Review

The groundwater project conducts special reviews of groundwater analytical data or field measurements when results are in question. Groundwater project staff document the process on a review form, and results are used to flag the data appropriately in HEIS. Various staff may initiate a review form: e.g., project scientists, data management staff, and quality control staff. The data review process includes the following steps:

- The initiator fills out required information on the review form, such as sample number, constituent, and reason for the request (e.g., "result is two orders of magnitude greater than historical results and disagrees with duplicate"). The initiator recommends an action, such as a data recheck, sample reanalysis, well resampling, or simply flagging the data as suspect in HEIS.

- The data review coordinator determines that the review form does not duplicate a previously submitted review form, then assigns a unique review form number and records it on the form. A temporary flag is assigned to the data in HEIS indicating the data are undergoing review ("F" flag).

- If laboratory action is required, the data review coordinator records the laboratory's response on the review form. Other documentation also may be relevant, such as chain-of-custody forms, field records, calibration logs, or chemist's sheets.

- A project scientist assigned to examine a review form determines and records the appropriate response and action on the review form including changes to be made to the data flags in HEIS. Actions may include updating HEIS with corrected data or result of reanalysis, flagging existing data (e.g., "R" for reject, "Y" for suspect, "G" for good), and/or adding comments. Data management staff updates the temporary "F" flag to the final flag in HEIS.

- The data review coordinator signs the review form to indicate its closure.

- If a review form is filed on data that are not "owned" by the groundwater project, the data review coordinator forwards a copy of the partially filled review form to the appropriate contact for their action. The review is then closed.

1.4.3 Interpretation

After data are validated and verified, the acceptable data are used to interpret groundwater conditions at the site. Interpretive techniques include:

- Hydrographs – graph water levels vs. time to determine decreases, increases, seasonal, or manmade fluctuations in groundwater levels.

- Water-table maps – use water-table elevations from multiple wells to construct contour maps to estimate flow directions. Groundwater flow is assumed to be perpendicular to lines of equal potential.

- Trend plots – graph concentrations of constituents vs. time to determine increases, decreases, and fluctuations. May be used in tandem with hydrographs and/or water-table maps to determine if concentrations relate to changes in water level or in groundwater flow directions.

- Plume maps – map distributions of chemical constituents are in the aquifer to determine extent of contamination. Changes in plume distribution over time aid in determining movement of plumes and direction of flow.

- Contaminant ratios – can sometimes be used to distinguish between different sources of contamination.

1.4.4 Reporting

Chemistry and water-level data are reviewed after each sampling event and are available in HEIS. Results of interpretation of groundwater monitoring are reported annually in March. Results of RCRA monitoring also are summarized in informal, quarterly reports sent to Ecology via e-mail.

PART II

Hydrogeology and Conceptual Model

This part provides an update of the local hydrogeology and the subsequent source conceptual model developed for the 216-U-12 crib.

This section summarizes available and new interpretations of the hydrogeology of the 216-U-12 crib. Data on physical characteristics of the 216-U-12 crib and the surrounding area (e.g., boreholes) are used to refine understanding of the hydrogeology beneath the site and the potential contaminant transport pathways from the subsurface, toward groundwater, and toward potential receptors. These data are used to develop the conceptual model beneath the site (Section 2.3). The conceptual model provided in this part focuses on the potential for movement of contamination deep in the vadose zone and potential impacts to the underlying unconfined aquifer. A more detailed conceptual model that develops the site-specific sediment and contaminant relationships existing in the shallow subsurface directly beneath the 216-U-12 crib will be provided by others. Early studies relied on limited borehole and well data to describe the stratigraphy and hydrogeology of the area. In recent years, more wells have been drilled in the surrounding area specifically targeted to collect more characterization data. As a result, the quantity and quality of the geologic data have been enhanced, which improves the hydrogeologic model development and its interpretation.

The 216-U-12 crib is located in the southeast 200 West Area on the Central Plateau, a broad, flat area that constitutes a local topographic high around the 200 Areas. The plateau is one of the flood bars (i.e., Cold Creek Bar) formed during the cataclysmic flooding events of the Missoula floods that occurred over 13,000 years ago. The north boundary of the flood bar is defined by an erosional channel, and present day topographic low, that runs northwest-southeast near Gable Butte just north of the 200 West Area boundary (Williams et al. 2002). Most of the 200 West Area, including the 216-U-12 crib, is situated on the flood bar (Figure 2.1).

The geology of the Central Plateau, and particularly the Pasco Basin, has been studied in great detail (DOE 1988). The focus of this section is on the sediment above the basalt bedrock, or the suprabasalt sediment, contained within the Hanford, Cold Creek (formerly Plio-Pleistocene), and Ringold Formations, because these strata comprise the uppermost aquifer system and vadose zone in the area. Detailed descriptions of these geologic units are available in Bjornstad (1984, 1985), DOE (2002b), Tallman et al. (1979), Myers and Price (1981), Graham et al. (1981), and Lindsey (1995). The most detailed description of the stratigraphy beneath the 216-U-12 crib could be found in Jensen et al. (1990).

Williams et al. (2002) provides an updated reinterpretation of the hydrogeology in the 200 West Area and vicinity that includes characterization of the entire suprabasalt aquifer system. The most recent description of the groundwater contamination in the region of the Hanford Site surrounding the 216-U-12 crib is presented in Section 2.8 of Hartman et al. (2003).

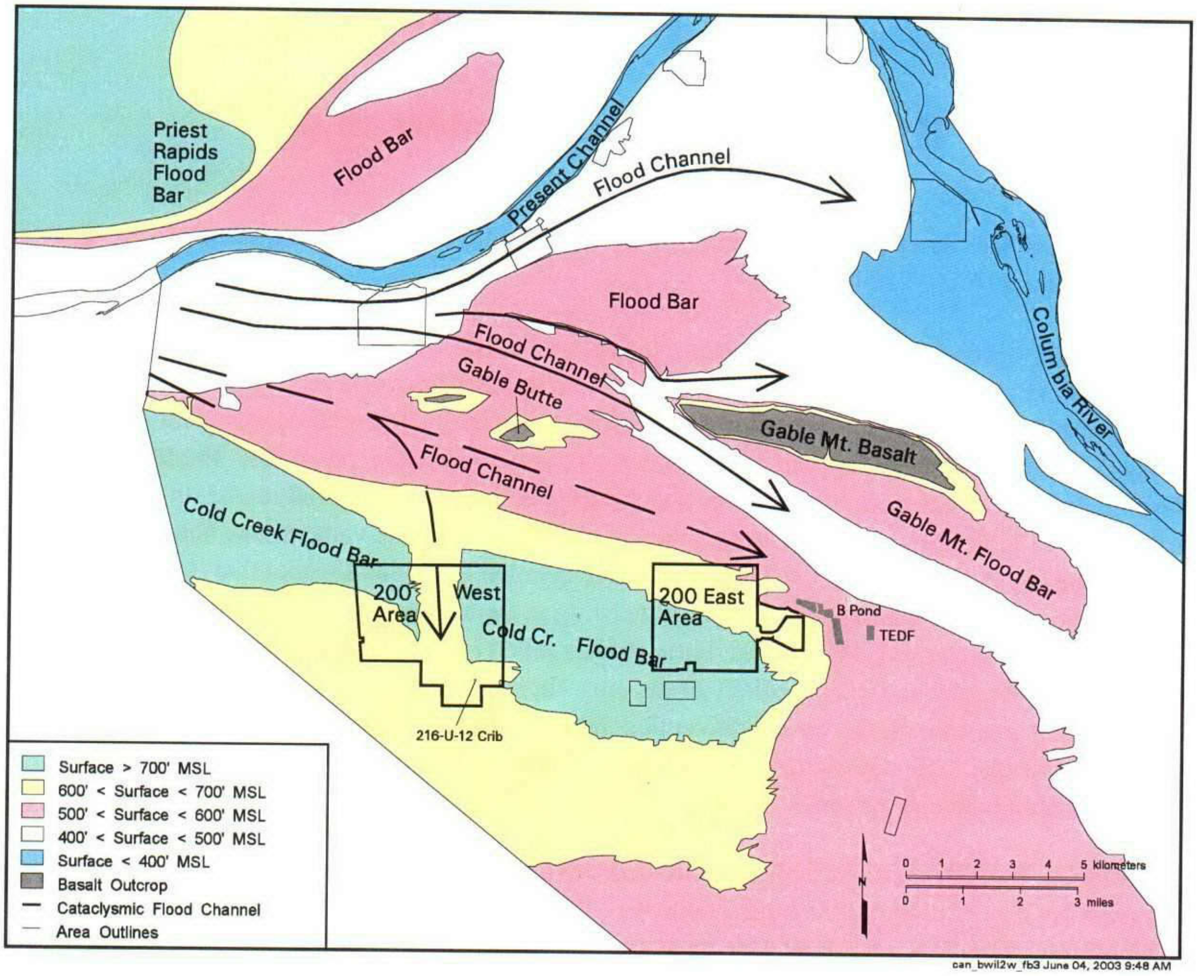

Figure 2.1. Topographic Illustration of Pleistocene Flood Channels and the Present Day Columbia River Channel Pathways, with Outlines of the 200 West and East Areas, Hanford Site, Washington

2.1 Stratigraphy

Two separate Hanford Site stratigraphic classifications are available (Figure 2.2); one developed by Lindsey (1995) is based on lithology (labeled Geology Column), and the second, developed by Pacific Northwest National Laboratory (PNNL) (Wurstner et al. 1995; Thorne et al. 1993), is the hydrogeologic stratigraphy (labeled Hydrogeologic Column) that combines the geology with the hydrologic properties of the sediment. This plan uses PNNL's hydrogeologic classification because it is more applicable to groundwater movement in the suprabasalt sediment. This hydrogeologic nomenclature and its geologic relationship are illustrated in Figure 2.2. The uppermost suprabasalt aquifer system is contained in the Ringold Formation, and the Hanford formation and Cold Creek (Plio-Pleistocene unit) comprise the vadose zone. The Ringold Lower Mud Unit (hydrogeologic unit 8) separates the supra basalt aquifer system into a confined and unconfined aquifer (Williams et al. 2002). The uppermost surface of the Elephant Mountain member basalt is considered the base of the suprabasalt aquifer system (bedrock)

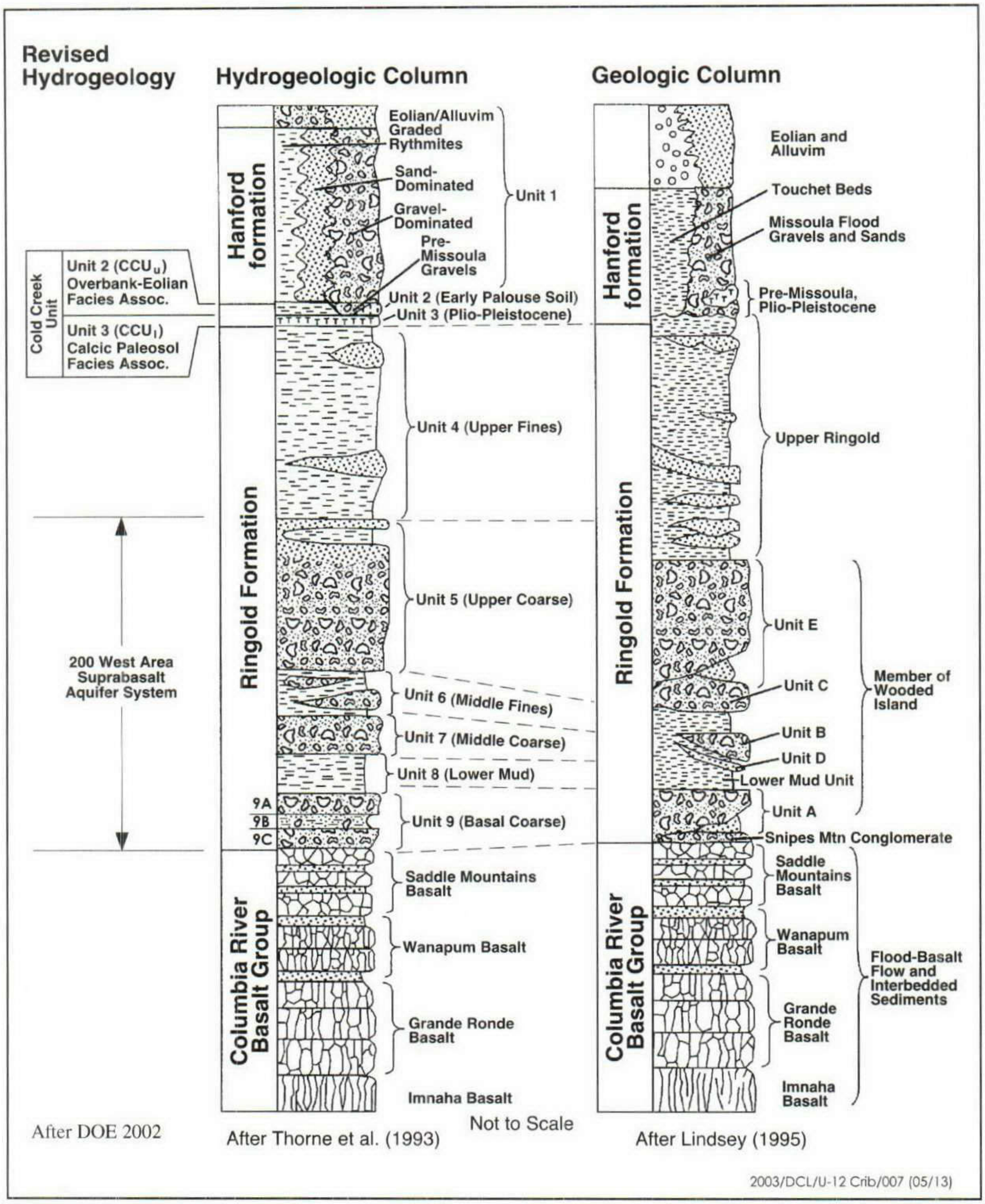

Figure 2.2. Comparison of Hydrogeologic and Geologic Classifications

because of its dense, low permeability interior, relative to the overlying sediments. This surface is considered to be a groundwater no-flow boundary. The basalt surface beneath the 216-U-12 crib dips south-southwest forming the southern limb of the Gable Mountain-Gable Butte anticline and the northeast flank of the Cold Creek syncline (after Fecht et al. 1987). Figures 2.3 (south-north) and 2.4 (east-west) illustrate the stratigraphic position and relationship of these hydrogeologic units as they exist beneath the south 200 West Area and the 216-U-12 crib. Figure 2.5 provides a more detailed hydrogeologic profile beneath the 216-U-12 crib.

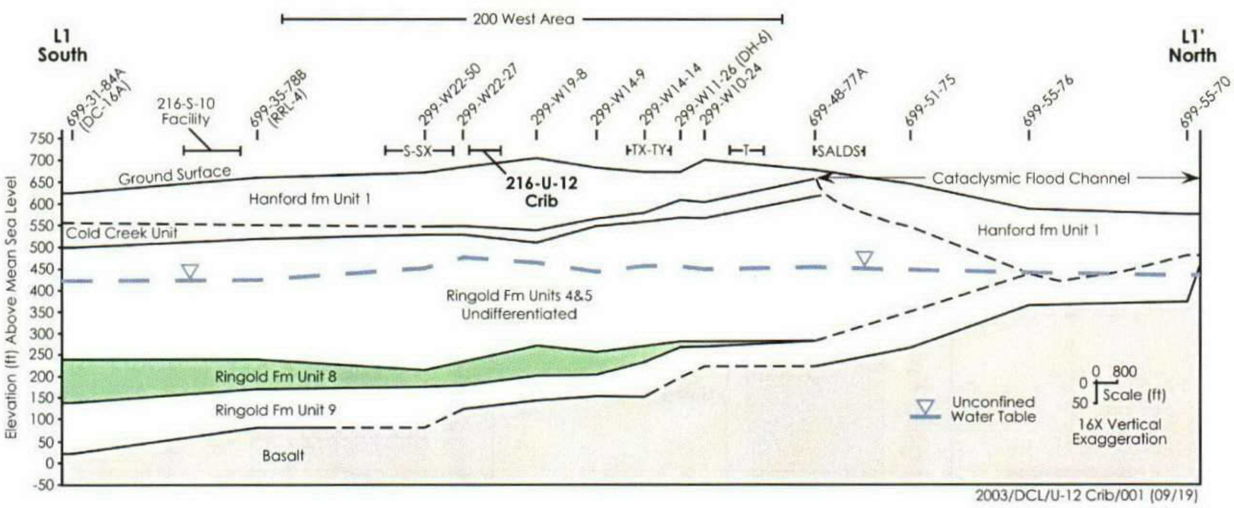

Figure 2.3. Hydrogeologic South-North Cross Section in the 200 West Area Near 216-U-12 Crib

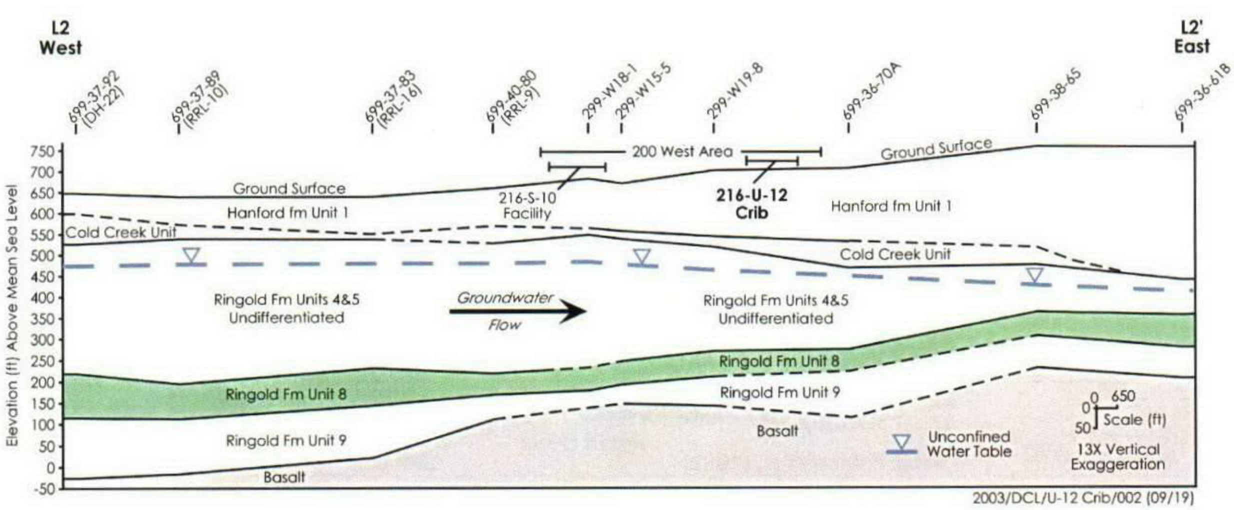

Figure 2.4. Hydrogeologic East-West Cross Section in the 200 West Area Near 216-U-12 Crib

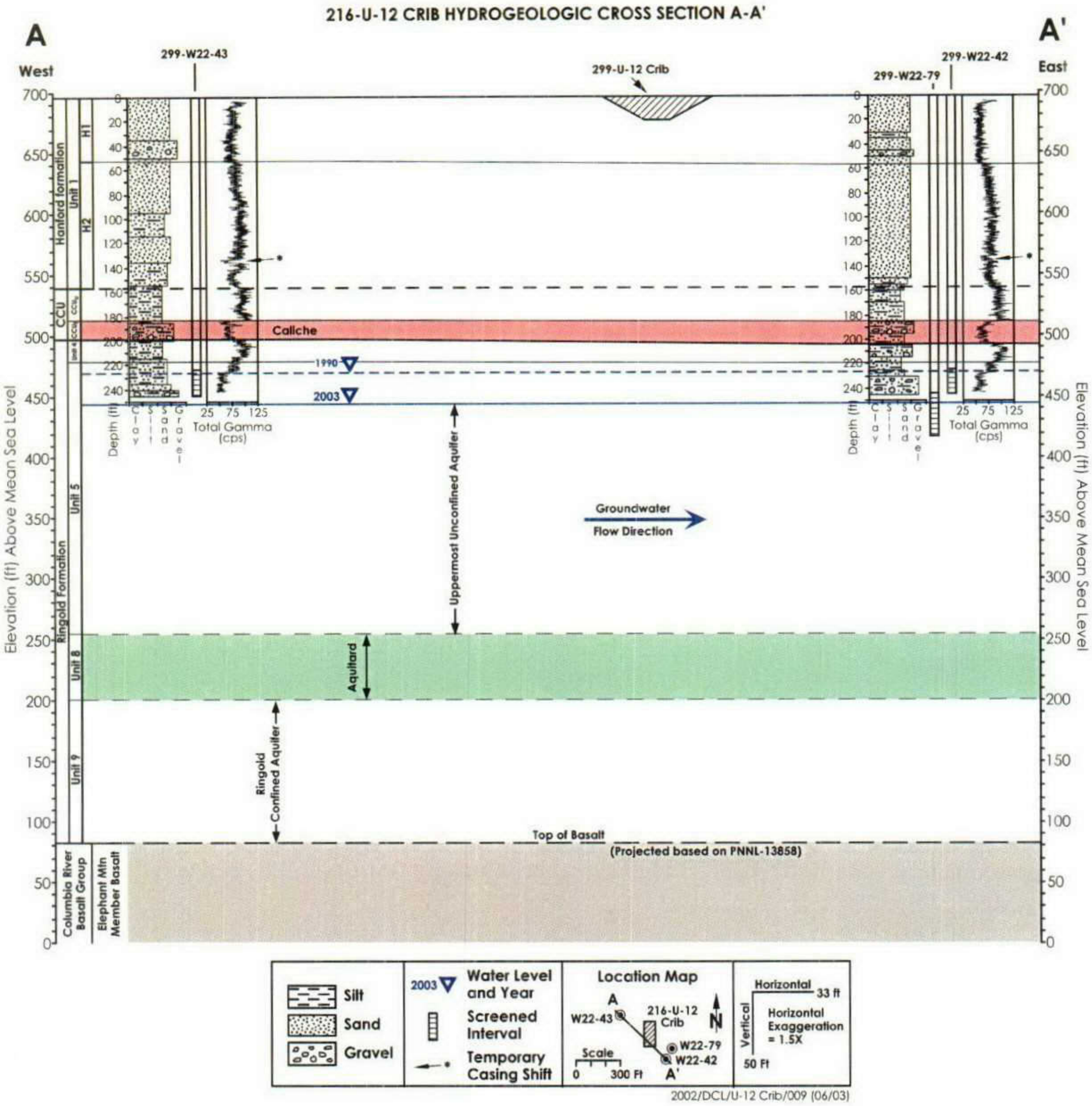

Figure 2.5. Detailed Hydrogeologic Cross Section at the 216-U-12 Crib

The 216-U-12 crib lies at an elevation of ~211 m (692 ft) above mean sea level. The suprabasalt stratigraphy at the 216-U-12 crib includes the following (from lower to upper):

- Ringold Formation.
- Cold Creek Unit (formerly Plio-Pleistocene Unit).
- Hanford formation.

Geology beneath the 216-U-12 crib is described in detail in the following sections from oldest to youngest.

2.1.1 Ringold Formation (Units 4 through 9)

Units 4 through 9 correspond to the Ringold Formation (Figure 2.2) and consist of continental fluvial and lacustrine sediments deposited on the Elephant Mountain member basalt by ancestral Columbia and Clearwater-Salmon Rivers during late Miocene to Pliocene time (DOE 1988). From the oldest to youngest, the hydrogeologic intervals are the Unit 9 fluvial gravel, Unit 8 composed of the paleosol/ overbank facies beneath lacustrine fine-grained facies (Bjornstad 1984; DOE 1988; Last et al. 1989; Bjornstad 1990), Unit 5 fluvial gravel, and Unit 4 fines.

Ringold Units 4 through 9 consist of intercalated layers of indurated to semi-indurated and/or pedogenically altered sediment, including clay, silt, fine-to-coarse grained sand, and granule-to-cobble gravel. Within the area of the 216-U-12 crib, this sequence consists of four distinct stratigraphic intervals designated Units 4, 5, 8, and 9. Units 5, 8, and 9 correspond generally to Lindsey's Ringold Formation fluvial gravel Unit E, lower mud unit and fluvial gravel Unit A, respectively (Figure 2.2).

Unit 9. The Ringold Unit 9 gravel is located 150 m (492 ft) beneath the 216-U-12 crib and is approximately 22 m (72 ft) thick. This unit dips to the south-southwest and lies uncomformably on top of the Columbia River Basalt. Unit 9 is composed primarily of semi-consolidated and cemented silty sandy gravel with secondary lenses and interbeds that can consist of gravel, gravely sand, sand, muddy sand, and/or silt/clay.

Unit 8 (Lower Mud Unit). Unit 8 is composed of a thick sequence of fluvial overbank, paleosol, and lacustrine silts and clay with minor sand and gravel. Unit 8 forms the most significant and extensive confining unit within the suprabasalt aquifer system at the Hanford Site (Williams et al. 2000). More detailed descriptions of Unit 8 (the lower mud unit) can be found in Lindsey (1995). This unit is approximately 9 m (30 ft) thick and located approximately 141 m (462 ft) beneath the 216-U-12 crib.

Unit 5. The Ringold Unit 5 gravel is a relatively thick unit, ranging up to 76 m (250 ft) thick, composed primarily of indurated fluvial gravel to silty sandy gravel and sand that grades upward into Unit 4 (interbedded fluvial sand and silt). Unit 5 has not been subdivided further due to the lack of distinctive and correlable stratigraphy or lithologic units. The saturated portion of Unit 5 comprises the uppermost unconfined aquifer and is over 65 m (213 ft) thick beneath the 216-U-12 crib. Unit 5 overlies the Unit 8 (Ringold lower mud unit).

Unit 4. The Ringold Unit 4 is only locally present in the 200 West Area, and consists of fluvial sand and silt that overlies the Ringold Unit 5 gravel. This unit is present in the wells surrounding the 216-U-12 crib. More information on the areal extent and details of this unit can be found in Lindsey (1995).

2.1.2 Cold Creek Unit (formerly Plio-Pleistocene Unit) (Units 2 and 3)

Units 2 and 3 represent relatively thin but significant depositional units that are post-Ringold and pre-Hanford sedimentation. Unit 3 is a calcic paleosol horizon that has developed on the eroded Ringold

Formation (either Unit 4 or 5). Unit 3 is commonly referred to as the calcic sequence (or "caliche" zone) and is also referred to as the lower Cold Creek Unit (CCU_l). Unit 2 is described as an overlying fine-grained overbank-eolian sequence considered to belong to the upper portion of the Cold Creek Unit (CCU_u) (DOE 2002). It is equivalent to what has been called the early "Palouse" soil (Connelly et al. 1992) and/or Plio-Pleistocene Unit in previous reports. Unit 3 is easily differentiated from the underlying (Unit 5) and overlying overbank-eolian sequence (Unit 2) because it is highly weathered, heavily cemented with calcium carbonate, poorly sorted, and shows a distinct decrease in natural gamma activity compared to the upper Unit 2. The Unit 2 is very fine grained, un-cemented, consisting of alternating thin lenses (typically less than 15.2 cm [6 in.]) of very fine sand to silt and clay, and has a relatively high natural gamma activity. The stratigraphic contact between the Unit 3 and the Ringold Unit 4 or 5 is fairly distinct and sharp, whereas the contact between the Unit 2 and the overlying Hanford Unit (H2) is gradational, dependent on grain size. In most cases, geophysical gamma logs greatly improve the accuracy of these correlations. Figure 2.5 illustrates these contacts beneath the facility.

At the 216-U-12 crib, the Unit 3 is relatively thick, ~4.6 m (15 ft). Unit 2 is ~9.1 m (30 ft) thick. Unit 2 is located approximately ~45.7 m (155 ft) in depth below the surface.

2.1.3 Hanford Formation (Unit 1)

The Hanford formation is the informal name given to Pleistocene-age cataclysmic flood deposits in the Pasco Basin (Lindsey et al. 1994). It consists predominantly of unconsolidated sediments, which cover a wide range in grain size from pebble- to boulder-gravel, fine- to coarse-grained pebbly sand to sand, silty sand, and silt. Gravel clasts are composed of mostly subangular to subrounded basalt. Beneath the 216-U-12 crib, the Unit 1 consists of essentially two facies, the lower facies (Hanford H_2 unit) is composed of fine-grained sand to sandy silt that ranges from 32 to 30.5 m (105 to 100 ft) in thickness. This fine-grained facies is overlain with a fine to coarse sand to sandy gravel sequence that is approximately 16 m (53 ft) in thickness. This coarse grained interval is designated the Hanford H_1 unit. The subtle but sharp contact between the two facies is indicated by slightly gravelly sand to sandy gravel above the thick fairly uniform fine sand of the H_2 unit. This contact is easily distinguishable with the aid of geophysical gamma logs at a depth of about 15.8 to 16.8 m (52 to 55 ft) (Figure 2.5).

2.2 Hydrogeology Beneath the 216-U-12 Crib

Information on the vadose zone and the suprabasalt aquifer system at the 216-U-12 crib is obtained from well-log data for wells and boreholes surrounding the facility and from published reports. In the 200 West Area and vicinity of 216-U-12 crib, Williams et al. (2002) used data from borehole and groundwater monitoring to subdivide the suprabasalt sediments into two aquifers, an upper unconfined (Hanford/Ringold unconfined) aquifer and a lower confined (Ringold confined) aquifer. The hydrogeology beneath the 216-U-12 crib utilizes their interpretation.

The uppermost aquifer beneath the 216-U-12 crib is unconfined; the aquifer comprises the saturated portion of the Upper Ringold Unit 4 and Ringold Unit 5 and is approximately 65.3 m (214 ft) thick (2003 measurement). Most known contaminant plumes that emanate from the 200 West Area migrate through Unit 5 toward the east. The groundwater flow direction is approximately toward the southeast and is estimated based on water-level measurements taken in network and surrounding wells (e.g., Figure 2.1-1 in Hartman et al. 2003).

Site-specific hydraulic conductivity values, derived from slug test data at well 299-W22-79 near the 216-U-12 crib, range from 4.2 to 5.4 m (13.8 to 17.7 ft) per day (Spane et al. 2001). These values are within the range of hydraulic conductivities presented in Table 2.1 that have been calculated for hydrogeologic units beneath the 200 West Area. These data reflect averages of data collected from wells throughout the Central Plateau. Based on these values and parameters listed in Hartman et al. (2003, Table A.2), the groundwater flow rate (Darcy velocity) ranges from 0.02 to 0.08 m (0.1 to 0.3 ft) per day.

Table 2.1. Hydraulic Conductivities for Major Hydrogeologic Units

Hydrogeologic Unit	Estimated Range of Saturated Hydraulic Conductivities (m/d)	Reference(s)
Unit 5 (Ringold Formation Unit E)	0.1 to 200	Wurstner et al. (1995); Thorne and Newcomer (1992)
Unit 8 (Ringold Formation Lower Mud Unit)	0.0003 to 0.09	Wurstner et al. (1995); Thorne and Newcomer (1992)
Unit 9 undifferentiated Ringold Formation Unit A	0.1 to 200	Wurstner et al. (1995); Thorne and Newcomer (1992)
Note: This table is modified from Cole et al. (1997).		

Within the 200 West Area, including the 216-U-12 crib, the water table is declining rapidly due to site-wide cessation of past (non-permitted) liquid effluent disposal practices. Hydrographs for monitoring wells near the 216-U-12 crib are presented in Figure 2.6. The falling water table is causing wells that monitor the 216-U-12 crib and surrounding monitoring wells to go dry (Figure 2.6). The preferred method used to intercept and monitor the uppermost aquifer flow zone(s) requires installation of longer screens to maximize the life of the well due to rapidly declining water levels. Monitoring screens are being installed up to 10 m (35 ft) long depending on location and aquifer thickness.

It is not known if preferential paths of groundwater flow exist in this thick uppermost aquifer, or if flow paths are changing due to falling water levels, because existing Unit 5 hydrogeologic data has not supported subdivision of the unit into more discrete flow zones. However, the depositional nature and character of this unit, and the lithologic variability between boreholes, indicates that lithologic variations do occur on all scales; the intrinsic hydrologic properties will influence groundwater movement.

The vertical variability in contaminant distribution in the aquifer near the 216-U-12 crib has been evaluated. Data from nearby wells indicate that contaminants from other disposal operations have spread vertically and laterally throughout most of the unconfined aquifer beneath the 200 West Area (Williams et al. 2002). For example, carbon tetrachloride, tritium, and nitrate have all been detected at depths below the screened interval in well 699-36-70A, located over 900 m (2,950 ft) downgradient of the 216-U-12 crib (Williams 1995).

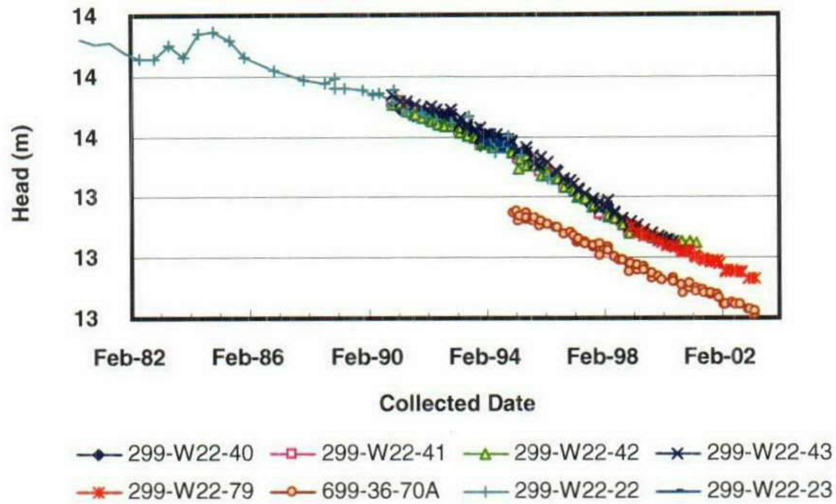

Figure 2.6. Hydrographs of Wells Monitoring the 216-U-12 Crib

The top of Unit 8 (lower mud unit) comprises the base of the uppermost-unconfined aquifer (Williams et al. 2002). South of the 216-U-12 crib the vertical hydraulic conductivity of Unit 8, as measured from a splitspoon soil sample collected in well 299-W27-2, is 0.051 m (0.17 ft) per day and falls within the expected range reported by Thorne and Newcomer (1992) (Table 2.1). Unit 8 (lower mud unit) is an aquitard and separates and confines groundwater in the underlying Ringold Unit 9 gravel (confined Ringold aquifer) from the unconfined aquifer in Unit 5. Groundwater in the confined Ringold aquifer is interpreted to flow laterally through Unit 9 gravel due to the thickness and relatively low vertical hydraulic conductivity of the overlying confining Unit 8.

Regionally, groundwater in the confined Ringold aquifer flows from west to east similar to groundwater in the uppermost unconfined aquifer. In the 200 West Area and around the 216-U-12 crib, it is more difficult to determine flow direction because there are currently no wells completed within the confined Ringold aquifer. Limited data are available below the confining Unit 8 (lower mud unit) for the 200 West Area; however, groundwater heads measured in several deep/shallow well pairs, and deep wells drilled into the Ringold Unit 9 confined aquifer (e.g., Johnson and Horton 2000) indicate a downward vertical hydraulic gradient beneath the 200 West Area from the unconfined Unit 5 into the confined Unit 9 (Williams et al. 2002).

Beneath the 216-U-12 crib, groundwater in the uppermost unconfined aquifer is assumed to be isolated from groundwater in the confined Ringold aquifer by Unit 8 (lower mud unit). Intercommunication between Units 5 and 9 is assumed to be insignificant beneath the 216-U-12 crib because groundwater flow through Unit 8 is extremely low due to the thickness and relatively low permeability of the confining unit.

The vadose zone beneath the 216-U-12 crib is approximately 76.4 m (251 ft) thick. The vadose zone includes hydrogeologic Units 1, 2, 3, and the upper, unsaturated portion of Units 4 and 5 (Figure 2.2).

Figure 2.5 provides input to the conceptual model for the area near the 216-U-12 crib and includes depths, relative thicknesses, and hydraulic relationship of the hydrogeologic units beneath the facility.

Recharge to the unconfined aquifer beneath the 216-U-12 crib is from artificial and possibly natural sources. Any natural recharge that occurs originates from precipitation. Estimates of recharge from precipitation range from 0 to 10 cm (0 to 4 in.) per year and are largely dependent on soil texture and the type and density of vegetation. While the liquid waste disposal facilities were operating, many localized areas of saturation or near saturation were created in the soil column. Artificial recharge from years of liquid effluent disposal accounts for most of the liquid influx to the aquifer and is the main driver and transport medium for potential contaminants disposed at the facility.

The downward flux of moisture in the vadose zone decreased with the cessation of artificial recharge in the 216-U-12 crib. Areas with high residual water saturation in the sediment will result in continued gravity drainage for an unknown period of time. When stable unsaturated conditions are reached, the moisture flux into the aquifer becomes less significant. In the absence of artificial recharge, the potential for recharge from precipitation becomes more important as a driving force for any potential contamination remaining in the vadose zone.

2.3 Conceptual Model

A groundwater conceptual model is an evolving hypothesis that identifies the important features, events and processes that control groundwater and contaminant movement (Hartman 2002). Conceptual models are based on data results, field observations, and previous studies and form the basis for future investigations and data collection objectives. The characteristics of the hydrogeologic and source conceptual model developed for the 216-U-12 crib are described in the following paragraphs.

A detailed conceptual model for the 216-U-12 crib is presented in Williams and Chou (1997). The following characteristics and working assumptions summarize that conceptual model for the 216-U-12 crib:

- Most of the hazardous (corrosive) waste that went into the crib was strongly acidic, composed primarily of nitric acid. This waste was also radioactive. Total volumes disposed to the crib exceeded 1.33×10^8 L (3.5×10^7 gal) from 1960 through 1978 (Maxfield 1979). The crib was permanently retired in 1988.

- The contaminated effluent infiltrated beneath the crib into the vadose zone, but the corrosive waste was neutralized by natural occurring calcium carbonate cement in vadose sediment before it reached groundwater. Most radioactive waste constituents remain sorbed, by design, to sediment in the thick vadose interval (>68 m [225 ft]) (Smith and Kasper 1983).

- Although process information suggests several mobile constituents may have been released to the crib (Figure 2.7), groundwater monitoring indicates that nitrate and technetium-99 (not RCRA dangerous waste constituents) are the only significant contaminants of concern that have been detected (Williams and Chou 1997). Nitrate and technetium-99 are mobile in the groundwater. The vadose zone

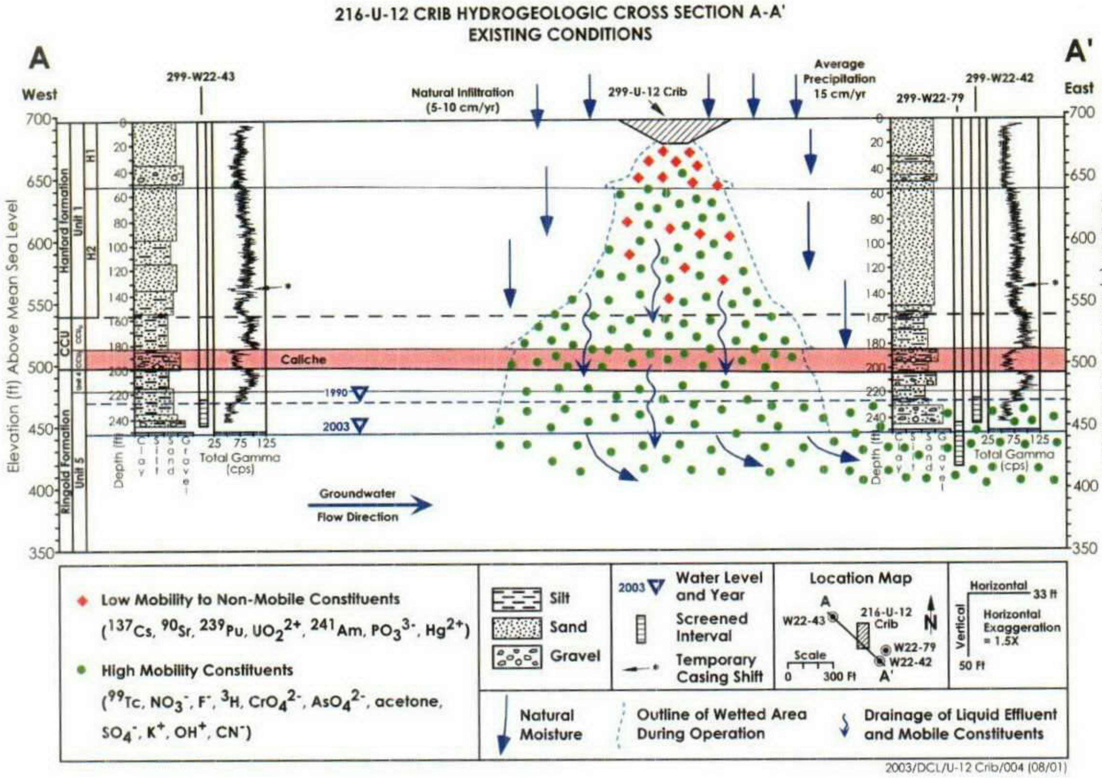

Figure 2.7. Conceptual Model Developed for the 216-U-12 Crib

is a continuing source of these constituents to the groundwater. Both nitrate and technetium-99 concentrations are declining as residual drainage from the vadose zone beneath the crib decreases.

- Nitrate and technetium-99 concentrations are higher in far field monitoring well 699-36-70A than in the wells immediately downgradient of the crib. This is due to the long groundwater travel time between the 216-U-12 crib and this well and reflects the passing of the higher concentration portion of the migrating plumes (i.e., reached groundwater years earlier than what is currently detected near the crib).

- The contaminant plumes extend east from the crib and mingle with other similar contaminant plumes from nearby and adjacent waste disposal facilities (e.g., 216-U-8 crib) creating a larger area of contamination downgradient of the 216-U-12 crib.

- Declining water levels in the 200 West Area have stranded some 216-U-12 wells above the water table and reduced the ability to track plumes and confirm these contaminant declines. Existing and replacement wells have indicated groundwater flow direction at the 216-U-12 crib has been essentially unchanged since monitoring began (June 1992 water-table map, Reidel 1993). No residual groundwater mound was ever observed.

The conceptual model developed for the 216-U-12 crib is that, during operation, semi-saturated to saturated flow conditions existed beneath the facility (Figure 2.7). The acidic liquid waste saturated into the vadose sediment where neutralization occurred as the waste moved deeper through calcium carbonate containing sediment. The buffering capacity of the thick sediments of the vadose zone was determined adequate to neutralize all nitric acid waste, liberating the nitrate anion which does not interact with sediment and thus continued to migrate with water through the vadose zone. Because technetium-99 also has essentially zero retardation, it also traveled with the nitrate in water migrating through the vadose zone to the aquifer.

The consistent relationship between the constituents indicates that the hydrogeologic processes acting on nitrate and technetium-99 and the migration pathway are essentially the same. RCRA assessment groundwater monitoring results downgradient of the crib indicate that continued migration of neutralized reaction constituents (nitrate and associated radionuclides) is still occurring. Continued drainage of mobile constituents from the vadose zone is expected based on vadose-transport modeling, which has estimated that the travel time for natural moisture within the vadose zone to migrate to the aquifer can take many years (Fayer and Walters 1995).

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Appendix A

Network Well Information

WELL SUMMARY SHEET

Page 1 of 1

Date: 9/30/98

Well ID: B8552	Well Name: 299-W22-79
Location: 1/4 mi South of U-Plant, 200W	Project: 1998 RCRA Drilling
Prepared By: DC Weekes — Date: 9/29/98	Reviewed By: EC Rafuse — Date: 10/02/98
Signature: DC Weekes	Signature: EC Rafuse

CONSTRUCTION DATA

Description

8" carbon steel protective casing 3' a.g. to 3' bgs.

4" ID Type 304 stainless steel riser: 2' a.g. – 242.7'

4" ID Type 304 stainless steel continuous wire wrap screen (0.010-in slot): 242.7'-277.8'

Portland cement 0' – 11.1'

Dry bentonite (1/4" & 3/8" pellets and medium chunks): 11.1' – 230.4'

Colorado Silica Sand (20-40 mesh): 230.4' – 282.6'

Slough 282.6' – 286.0'

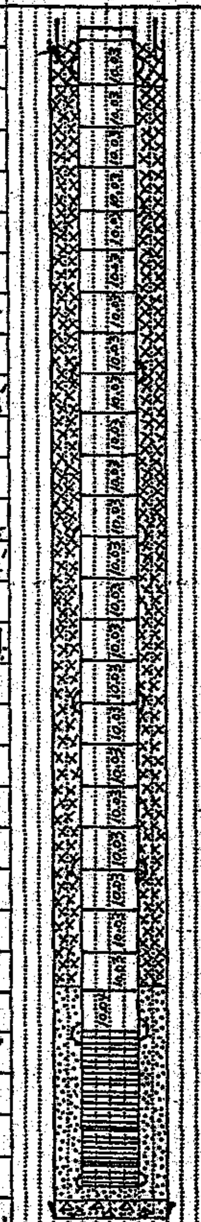
SS Centralizers above and below the screen and every 40 ft and as indicated

Water level (9/30/98): 241.91'

All temporary casing removed.

All depths are in ft below ground

Diagram



Depth in Feet: 0, 50, 100, 150, 200, 250

GEOLOGIC/HYDROLOGIC DATA

Graphic Log

Lithologic Description

0'-12': Silty SAND

12'-34': Gravelly SAND

34'-94': SAND

thin layers of silty sand 76'-78'

thin layers of silty sand @ 85' & 88'

94'-98': Silty SAND

98'-104': SAND

104'-125': Silty SAND

125'-128': SAND

128'-132': Silty SAND

132'-138': SAND

138'-156': Silty SAND

156'-161': SILT

161'-187': Sandy SILT

187'-194': Silty Sandy GRAVEL

194'-226': Sandy SILT

226'-236': SAND

236'-238': Slightly Silty Gravelly SAND

238'-245': Gravelly SAND

245'-270': Sandy GRAVEL

270'-286': Silty Sandy GRAVEL

TD @ 286' 9/26/98

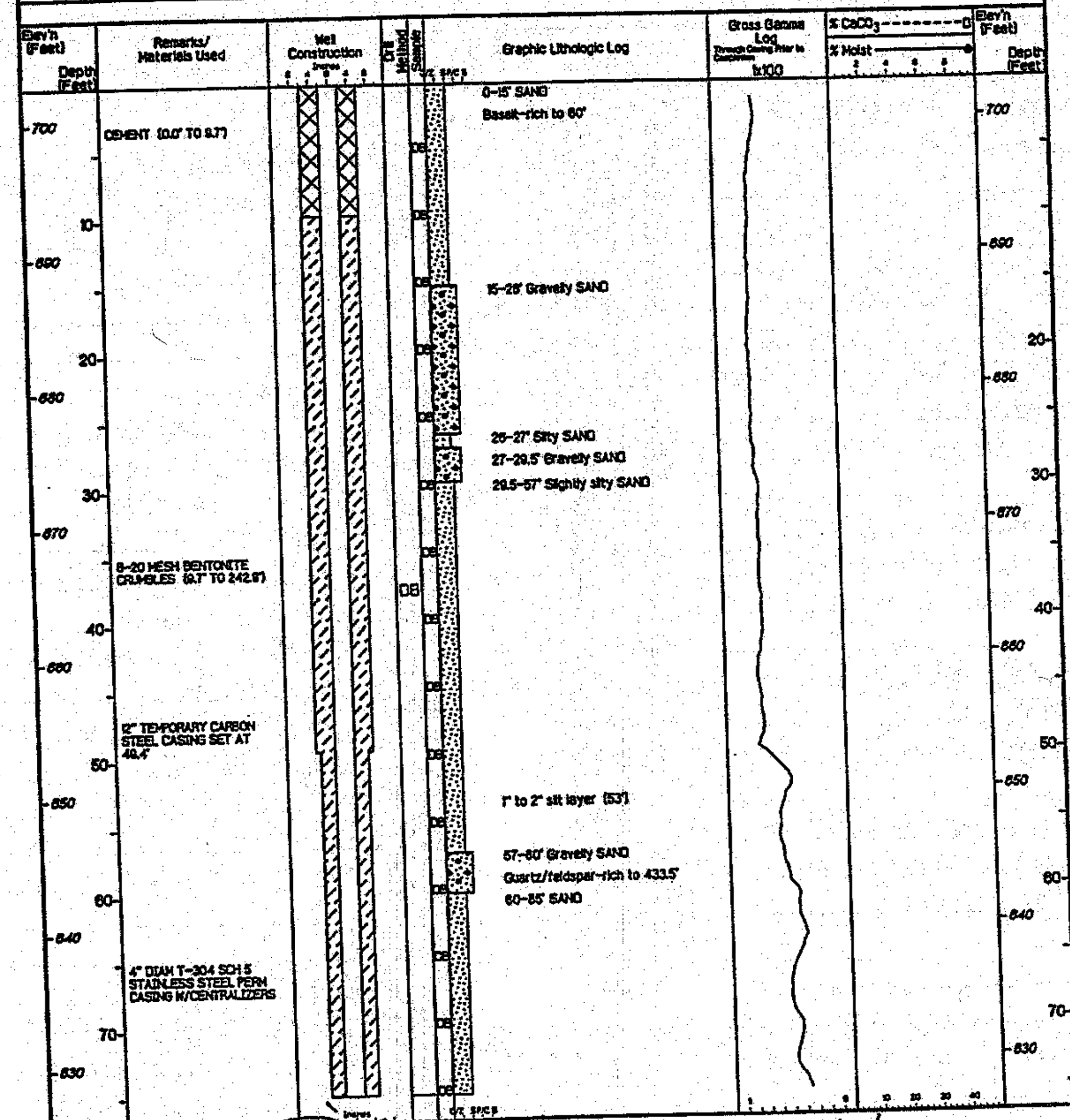
Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION		**Well No:** 699-38-70A	
		Total Depth: 440	**Static Water Level:** 257.85
		Surface Elevation: 702.74	**Casing Elevation:** 705.43
Date Started: 9-8-94	**Date Completed:** 5-11-95	**Northing:** 134308.839	**Easting:** 568466.679
Location: 200' E OF 200W PERIMETER FENCE		**Hanford N:** 35576.56	**Hanford W:** 70312.20
Prepared By: CE DEGENHART, et. al.		**Drill Meth:** CABLE TOOL	**Drill Equip:** N/A
Drilling Co: KEH	**Driller:** C WANSLEY/K OLSON		

Screen: 30.26' OF 4" DIAMETER 10-SLOT TYPE 304 STAINLESS STEEL CONTINUOUS WIREWRAP SET FROM 257.48' TO 287.74'

Filter Pack: 20-40 MESH SILICA SAND FROM 248.9' TO 289.5'

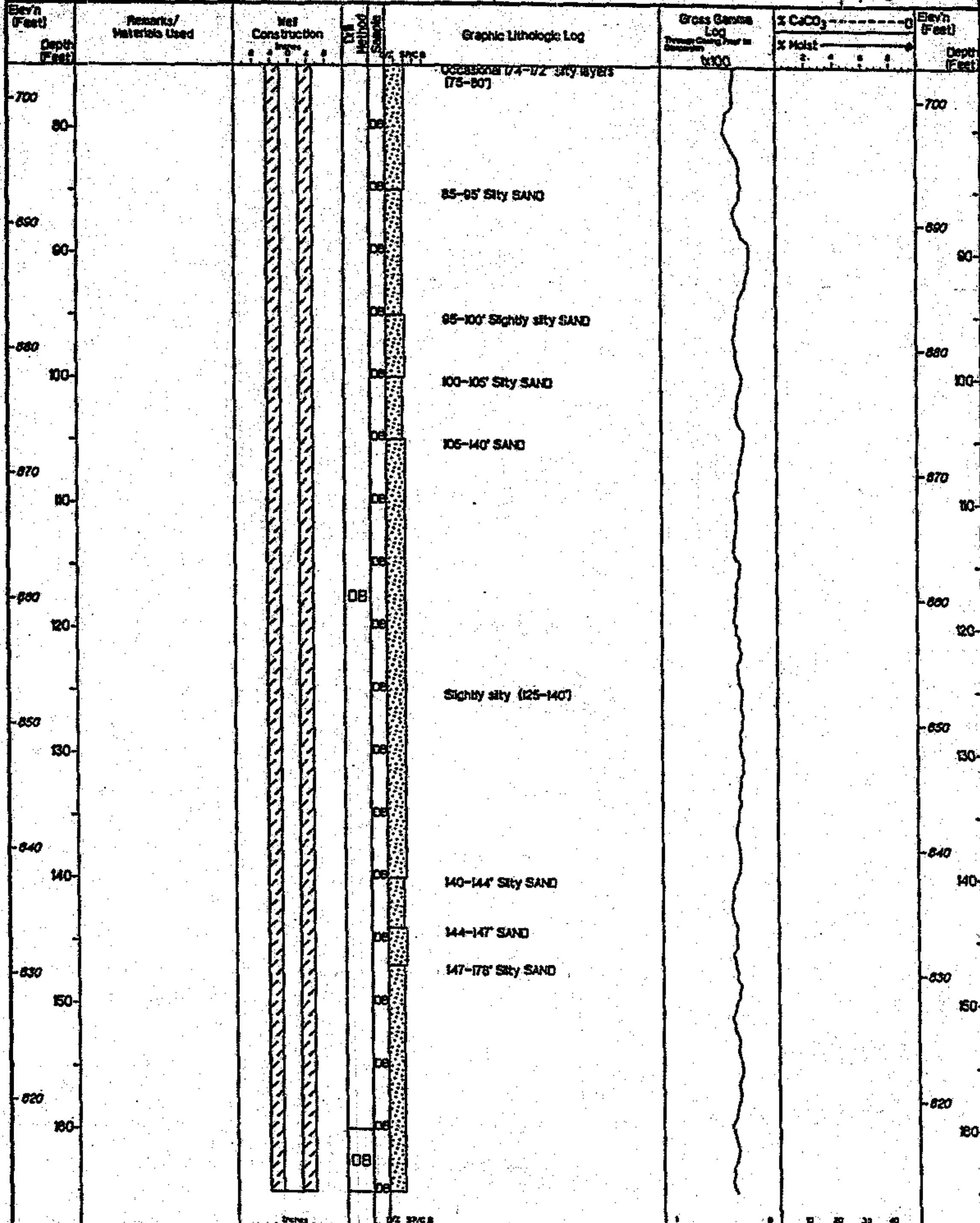
Permanent Casing: 4" DIAMETER TYPE 304 SCHEDULE 5 STAINLESS STEEL WITH CENTRALIZERS SET TO 257.48'

Comments:



Reviewed By: [signature] Date: 2/5/95

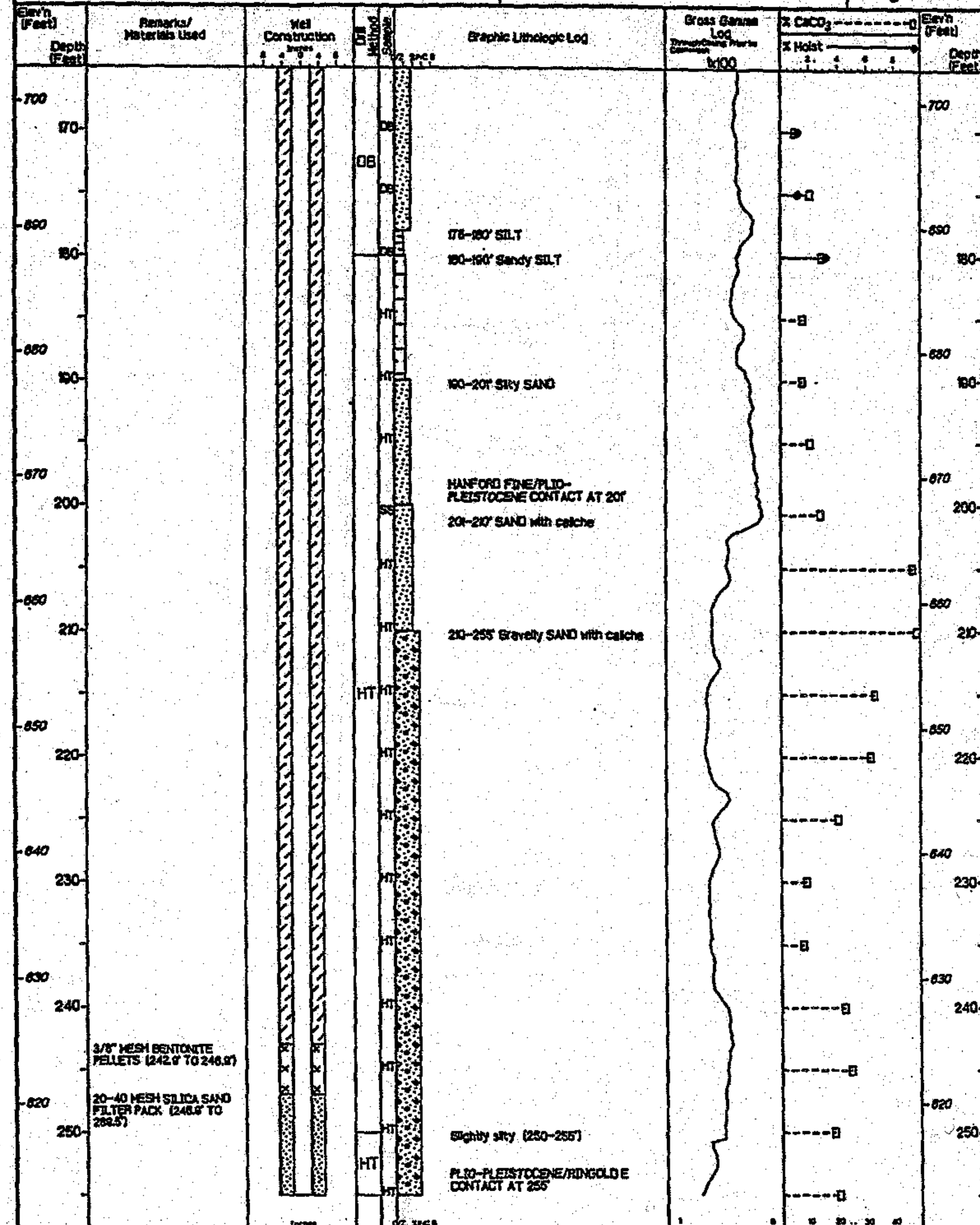
Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION | **Well No:** 699-36-70A |



Reviewed By: [signature] Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

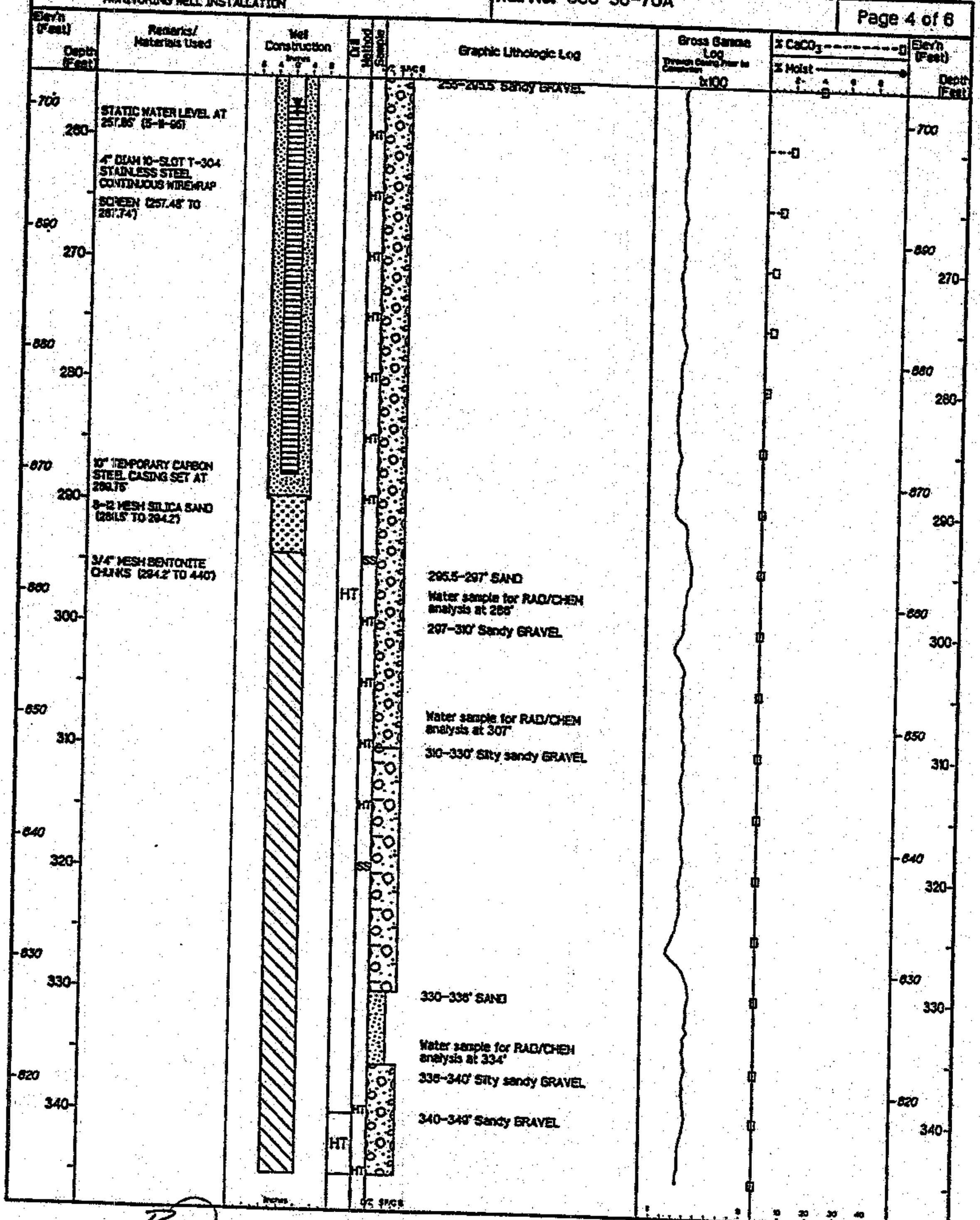
Well No: 699-36-70A



Reviewed By: [signature]   Date: 7/5/85

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A

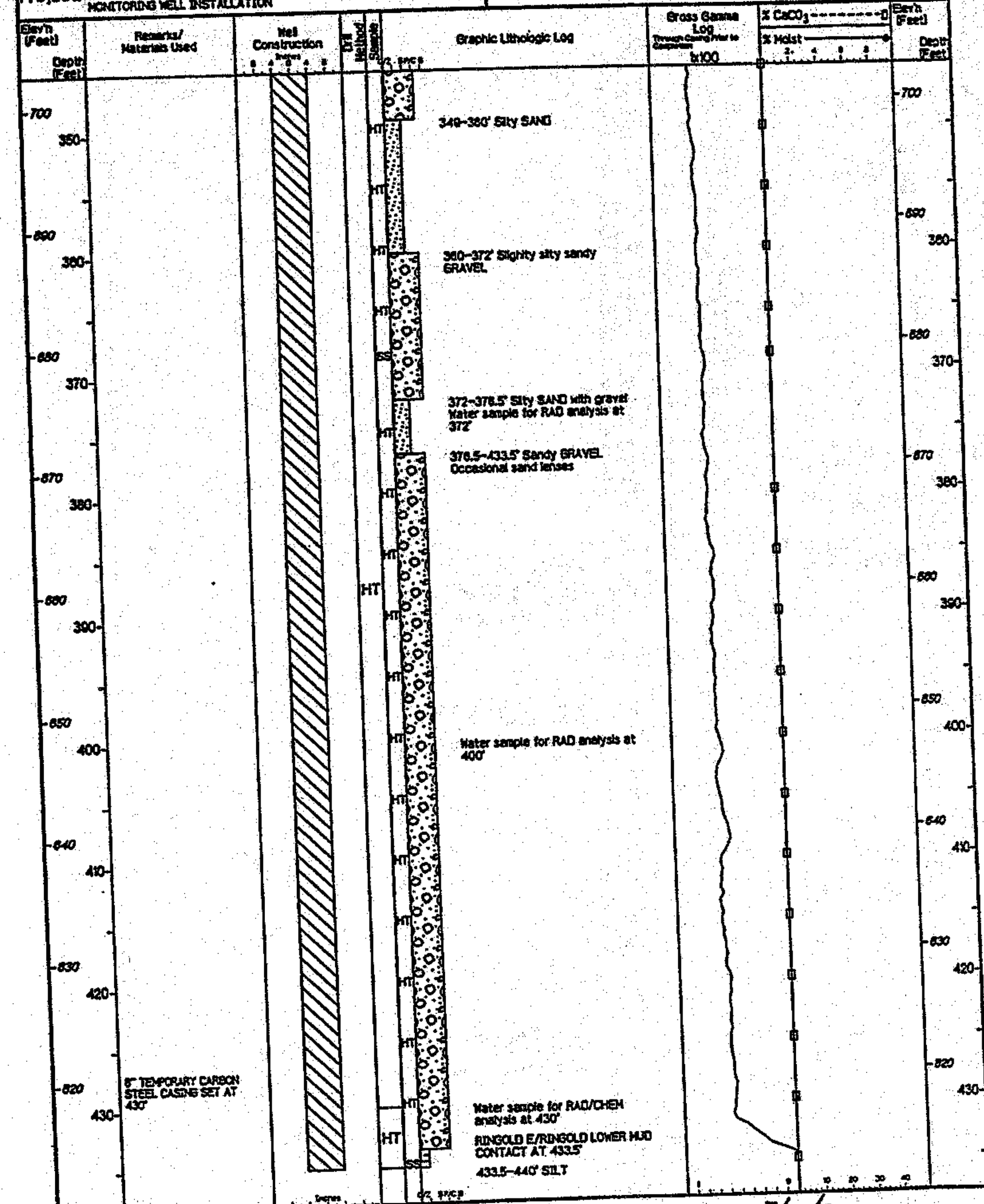


Reviewed By: [signature]

Date: 7/5/95

Project: W-162/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A



Reviewed By: [signature]

Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A

Elev'n (Feet)	Depth (Feet)	Remarks/ Materials Used	Well Construction (Inches)	Drill Method	Sample	Graphic Lithologic Log (G/Z S/P/C B)	Gross Gamma Log (Through Casing Prior to Completion) 1x100	% CaCO3 / % Moist	Elev'n (Feet)	Depth (Feet)
700	440	TOTAL DEPTH = 440'		HT	HT				700	
690	450								690	450
680	460								680	460
670	470								670	470
660	480								660	480
650	490								650	490
640	500								640	500
630	510								630	510
620	520								620	520

Reviewed By: [signature]

Date: 7/5/95

Appendix B

Data Logs for Well 299-W22-75

Stoller
Grand Junction Office established 1959

299-W22-75 (A7879)
Log Data Report

Borehole Information:

Borehole:	299-W22-75 (A7879)		Site:	216-U-12 Crib	
Coordinates (WA State Plane)		GWL (ft)[1]:	Not reached	GWL Date:	5/22/03
North	East	Drill Date	TOC[2] Elevation	Total Depth (ft)	Type
134,490.42 m	567,595.19 m	April 1982	211.586 m	176.25	Cable tool

Casing Information:

Casing Type	Stickup (ft)	Outer Diameter (in.)	Inside Diameter (in.)	Thickness (in.)	Top (ft)	Bottom (ft)
Threaded Steel	1.25	6 11/16	6	0.344	+1.25	169
Threaded Steel	0.5	8 5/8	Unknown	Unknown	+0.5	60

The logging engineer measured the casing stickup using a steel tape. A caliper was used to determine the outside casing diameter. The caliper and inside casing diameter were measured using a steel tape, and measurements were rounded to the nearest 1/16 in. Casing thickness was calculated.

Borehole Notes:

Borehole coordinates, elevation, and well construction information, as shown in the above tables, are from measurements by Stoller and Duratek field personnel, Ledgerwood (1993), and HWIS[3]. Zero reference is the top of the 6-in. casing. Grout is not present at the surface in the annulus between the casings but is observed on the ground surface surrounding the 8-in. casing.

Logging Equipment Information:

Logging System:	Gamma 2E		Type: 70% HPGe (34TP40587A)
Calibration Date:	03/2003	Calibration Reference:	GJO-2003-430-TAC
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 1C		Type: High Rate Detector (39A314)
Calibration Date:	04/2003	Calibration Reference:	GJO-2003-429-TAC
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	1	2	3	4/ Repeat	
Date	5/22/03	5/22/03	5/27/03	5/27/03	
Logging Engineer	Spatz	Spatz	Spatz	Spatz	
Start Depth (ft)	176.0	59.0	44.0	82.0	
Finish Depth (ft)	58.0	43.0	2.0	64.0	
Count Time (sec)	100	200	200	100	
Live/Real	R	R	R	R	

Log Run	1	2	3	4/ Repeat	
Shield (Y/N)	N	N	N	N	
MSA Interval (ft)	1.0	1.0	1.0	1.0	
ft/min	N/A[4]	N/A	N/A	N/A	
Pre-Verification	BE031CAB	BE031CAB	BE032CAB	BE032CAB	
Start File	BE031000	BE031119	BE032000	BE032043	
Finish File	BE031118	BE031135	BE032042	BE032061	
Post-Verification	BE031CAA	BE031CAA	BE032CAA	BE032CAA	
Depth Return Error (in.)	N/A	0	0	0	
Comments	Fine gain adjustments made after files: -012, -023, -077, and -118.	No fine-gain adjustment.	No fine-gain adjustment.	No fine-gain adjustment.	

High Rate Logging System (HRLS) Log Run Information:

Log Run	1	2/Repeat			
Date	6/03/03	6/03/03			
Logging Engineer	Spatz	Spatz			
Start Depth (ft)	27.0	26.0			
Finish Depth (ft)	20.0	24.0			
Count Time (sec)	300	300			
Live/Real	R	R			
Shield (Y/N)	N	N			
MSA Interval (ft)	1.0	1.0			
ft/min	N/A	N/A			
Pre-Verification	AC071CAB	AC071CAB			
Start File	AC072000	AC072008			
Finish File	AC072007	AC072010			
Post-Verification	AC072CAA	AC072CAA			
Depth Return Error (in.)	N/A	0			
Comments	No fine-gain adjustment.	No fine-gain adjustment.			

Logging Operation Notes:

Zero reference was top of the 6-in. casing. Logging was performed with a centralizer installed on the sonde. Pre- and post-survey verification measurements for the SGLS were acquired with the Amersham KUT (^{40}K, ^{238}U, and ^{232}Th) verifier with serial number 118. HRLS data were collected using Gamma 1C. Pre- and post-survey verification measurements for the HRLS were acquired with the ^{137}Cs verifier with serial number 1013.

Analysis Notes:

Analyst:	Sobczyk	Date:	6/5/03	Reference:	GJO-HGLP 1.6.3, Rev. 0

SGLS pre-run and post-run verification spectra were collected at the beginning and end of the day. All of the verification spectra were within the control limits except for pre-run verification spectrum BE031CAB. BE031CAB was below the lower control limit for the 609-keV, 1461-keV, and 2615-keV full-width at half-maximum values. The peak counts per second (cps) at the 609-keV, 1461-keV, and 2615-keV photopeaks on the post-run verification spectra as compared to the pre-run verification spectra for each day were between 0.3 and 2.4 percent lower at the end of the day. Examinations of spectra indicate that the detector appears to have functioned normally during logging, and the spectra are accepted.

HRLS pre-run and post-run verification spectra were collected at the beginning and end of the day. The spectra were within the acceptance criteria for the field verification of the Gamma 1C logging system (HRLS).

Log spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Post-run verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations were calculated in EXCEL (source files: G2EMar03.xls and G1CApr03). Zero reference was the top of the 6-in. casing. On the basis of Ledgerwood (1993), the casing configuration was assumed to be a string of 8-in. casing with a thickness of 0.322 in. to 60 ft, a string of 6-in. casing with a thickness of 0.344 in. to 168 ft, and open-hole below 168 ft. The 8-in. casing thickness of 0.322 in. is the published value for ASTM schedule-40 steel pipe (a commonly used casing material at Hanford). Where more than one casing exists at a depth, the casing correction is additive (e.g., the correction for both the 8-in. and 6-in. casing would be 0.322 in. + 0.344 in. = 0.666 in.). A water correction was not needed or applied to the data.

Using the SGLS, dead time greater than 40 percent was encountered in the interval from 21 to 26 ft, and data from this region were considered unreliable. At SGLS dead time greater than 40 percent, peak spreading and pulse pile-up effects may result in underestimation of activities. This effect is not entirely corrected by the dead time correction, and the extent of error increases with increasing dead time. SGLS dead time corrections were applied when dead time surpassed 10 percent. The HRLS was utilized to obtain data where the SGLS dead time exceeded 40 percent.

Log Plot Notes:

Separate log plots are provided for gross gamma and dead time, naturally occurring radionuclides (^{40}K, ^{238}U, and ^{232}Th), and man-made radionuclides. Plots of the repeat logs versus the original logs are included. In addition, a comparison log plot of man-made radionuclides is provided to compare the data collected by Westinghouse Hanford Company's Radionuclide Logging System (RLS) with SGLS data. For each radionuclide, the energy value of the spectral peak used for quantification is indicated. Unless otherwise noted, all radionuclides are plotted in picocuries per gram (pCi/g). The open circles indicate the minimum detectable level (MDL) for each radionuclide. Error bars on each plot represent error associated with counting statistics only and do not include errors associated with the inverse efficiency function, dead time correction, or casing correction. These errors are discussed in the calibration report. A combination plot is also included to facilitate correlation. The ^{214}Bi peak at 1764 keV was used to determine the naturally occurring ^{238}U concentrations on the combination plot rather than the ^{214}Bi peak at 609 keV because it is less affected by the presence of radon in the borehole.

Results and Interpretations:

^{137}Cs, ^{235}U (based on the 186-keV photopeak), and ^{238}U (based on the 1001-keV photopeak) were the man-made radionuclides detected in this borehole. ^{137}Cs was detected in the interval from 17 to 61 ft with concentrations ranging from 0.3 to 8,400 pCi/g. The maximum concentration of ^{137}Cs was measured at 25 ft. ^{137}Cs was detected at a depth of 12 ft with a concentration near the MDL (0.2 pCi/g). ^{238}U was detected in the intervals from 17 to 20 ft, 29 to 31 ft, 37 to 53 ft, and 61 to 81 ft with an MDL of at least 10 pCi/g. In the interval from 17 to 20 ft, ^{238}U was detected with concentrations ranging from 55 to 330 pCi/g. In the interval from 29 to 31 ft, ^{238}U was detected with concentrations ranging from 20 to 30 pCi/g. In the interval from 37 to 53 ft, ^{238}U was detected with concentrations ranging from 17 to 75 pCi/g. ^{238}U was detected in the interval from 61 to 81 ft with concentrations ranging from 17 to 335 pCi/g. The maximum concentration of ^{238}U was measured at 76 ft, although the highest concentration may be in the interval of high dead time where the MDL significantly increases. ^{235}U was detected in the intervals from 18 to 19 ft, 68 to 81 ft, and at 44 ft with an MDL of at least 1.5 pCi/g. ^{235}U concentrations ranged from 6 to 9 pCi/g at 18 and 19 ft. In the interval from 68 through 81 ft, ^{235}U concentrations ranged from 1.8 to 22 pCi/g. ^{235}U was detected at a depth of 44 ft with a concentration of 5 pCi/g. It is probable that ^{235}U exists in the same intervals as the ^{238}U (based on the 1001-keV photopeak), but the ^{235}U concentration falls below its respective MDL.

The behavior of the naturally occurring ^{238}U log (measured by ^{214}Bi) suggests that radon may be present inside the borehole casing. Determination of ^{238}U is based on measurement of gamma activity at 609 and/or 1764 keV associated with ^{214}Bi, under the assumption of secular equilibrium in the decay chain. However, ^{214}Bi is also a short-term daughter of ^{222}Rn. When radon is present, ^{214}Bi will tend to "plate" onto the casing wall and will quickly reach equilibrium with ^{222}Rn. Because the additional ^{214}Bi resulting from radon is on the inside of the casing, the effect of the casing correction is to amplify the 609 photopeak relative to the 1764 photopeak. (The magnitude of the casing correction factor decreases with increasing energy, but gamma rays originating inside the casing are not attenuated.) The reason for variations in radon content between log runs on successive days is not known. Variations in radon content in boreholes are probably related to variations in surface weather conditions. Radon daughters such as ^{214}Bi may also "plate" onto the sonde itself. When this occurs, there is a gradual increase in total counts as well as photopeak counts associated with ^{214}Bi and ^{214}Pb. This phenomenon appears to best explain the observed discrepancy in ^{238}U values based on 609 keV versus those based on 1764 keV between 82 and 44 ft.

The presence of radon is not an indication of man-made contamination; it is derived from decay of naturally occurring uranium. As a gas, radon moves easily in the subsurface, and concentrations of radon and its associated progeny can change quickly.

The plots of the repeat logs demonstrate reasonable repeatability of the HRLS and SGLS data. ^{137}Cs (662-keV) concentrations are comparable between the repeat and original HRLS log runs. Taking into account the effects of radon, the plots of the repeat logs demonstrate reasonable repeatability of the SGLS data for the man-made radionuclides and natural radionuclides at energy levels of 186, 662, 1001, 1461, 1764, and 2614 keV.

Recognizable changes in the KUT logs occurred in this borehole. A gradual increase of approximately 8 pCi/g in apparent ^{40}K concentrations occurs between 30 and 62 ft. Above 20 ft, ^{40}K concentrations are relatively low, which indicates the surface seal of grout around the borehole reported by Ledgerwood (1993). ^{232}Th concentrations increase by 0.5 pCi/g at 19 ft. The increase in ^{40}K and ^{232}Th concentrations at 37 ft may correspond with the silt layer identified at 37 ft in the geologist's log (Ledgerwood 1993).

Comparison log plots of data collected in 1991 by Westinghouse Hanford Company and in 2003 by Stoller are included. The 1991 concentration data for ^{137}Cs are decayed to the date of the HRLS logging event in June 2003 and shifted from a ground level reference to a TOC reference. The RLS tool saturated in the interval from 21 to 27 ft. On the 2003 logs, the apparent ^{137}Cs concentrations are as predicted by decay alone when compared to the 1991 log except for the depths of 138, 148, 164, and 166 ft. The report written at the time of the 1991 RLS logging event reported that no man-made radionuclides were detected below 80 ft. Comparing the two logging events, the $^{235/238}U$ concentrations based on the RLS appear slightly higher than the SGLS.

Because of the presence of $^{235/238}U$ in the vadose zone, it is recommended that this borehole be logged periodically to verify that changes in $^{235/238}U$ concentrations are not occurring. The interval from ground surface to total depth should be logged again in 5 years.

References:

Ledgerwood, R.K., 1993. *Summaries of Well Construction Data and Field Observations for Existing 200-West Resource Protection Wells*, WHC-SD-ER-TI-005, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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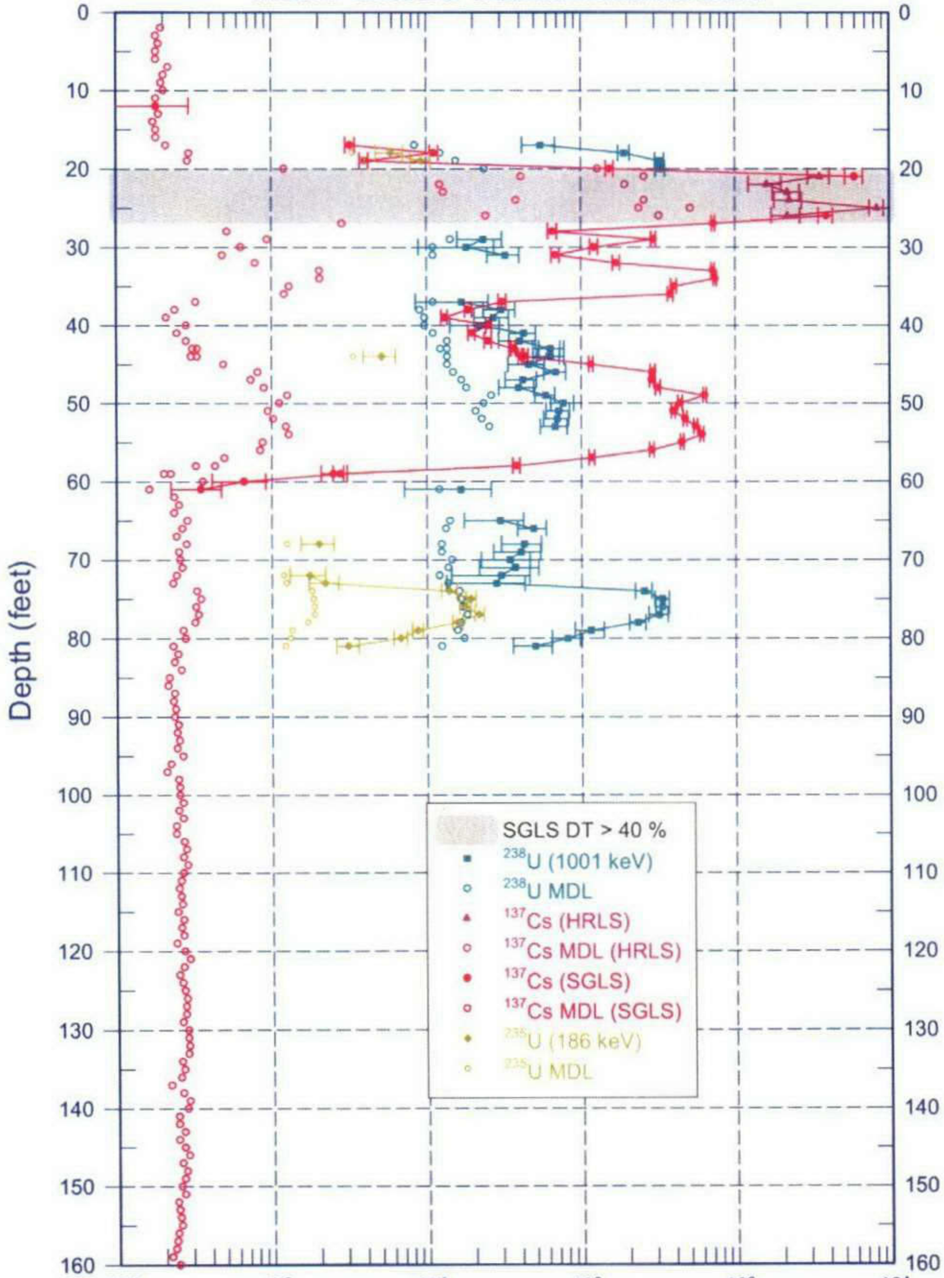
[1] GWL – groundwater level
[2] TOC – top of casing
[3] HWIS – Hanford Well Information System
[4] N/A – not applicable

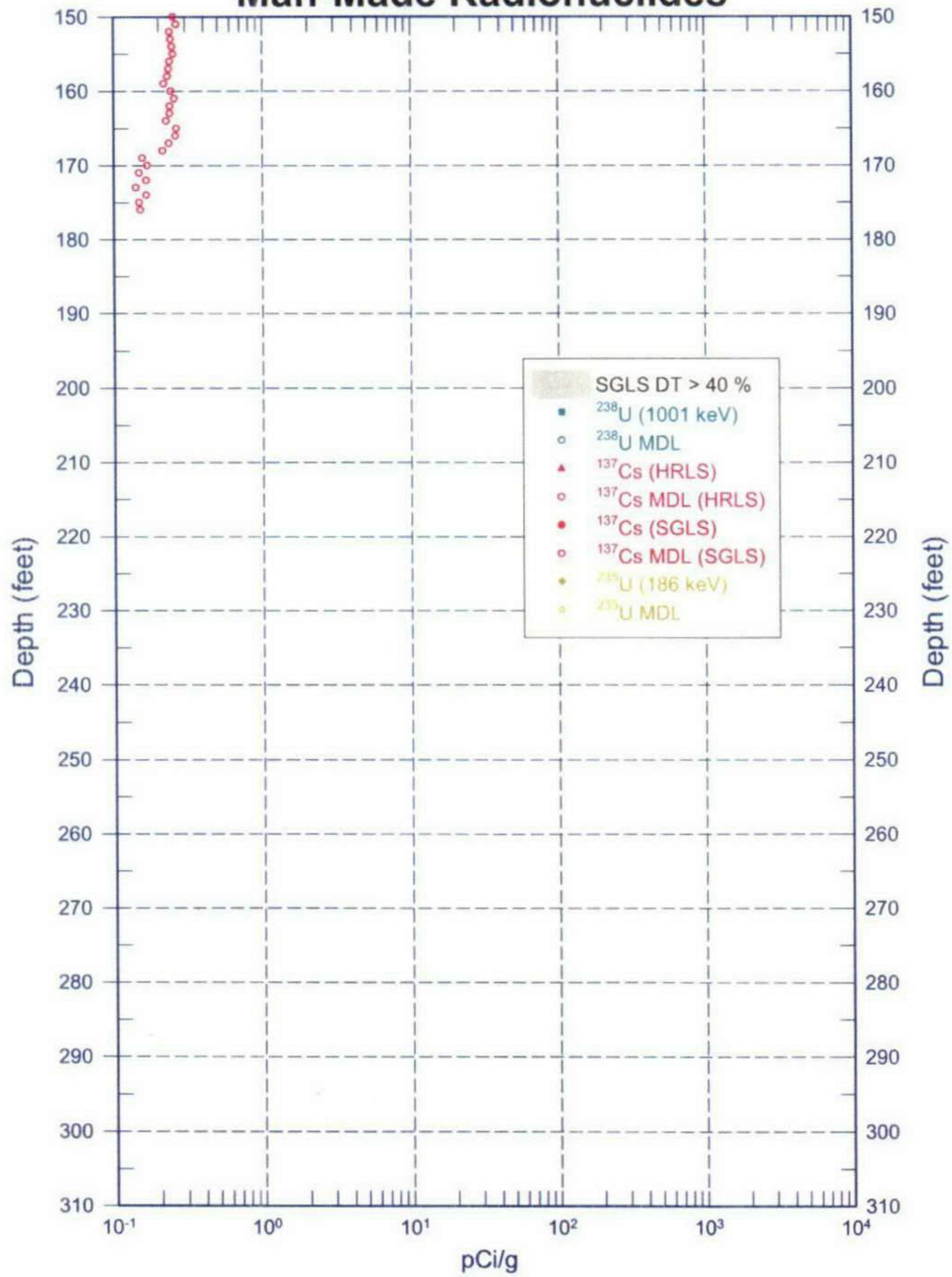
299-W22-75 (A7879)
Man-Made Radionuclides



Zero Reference = Top of Casing

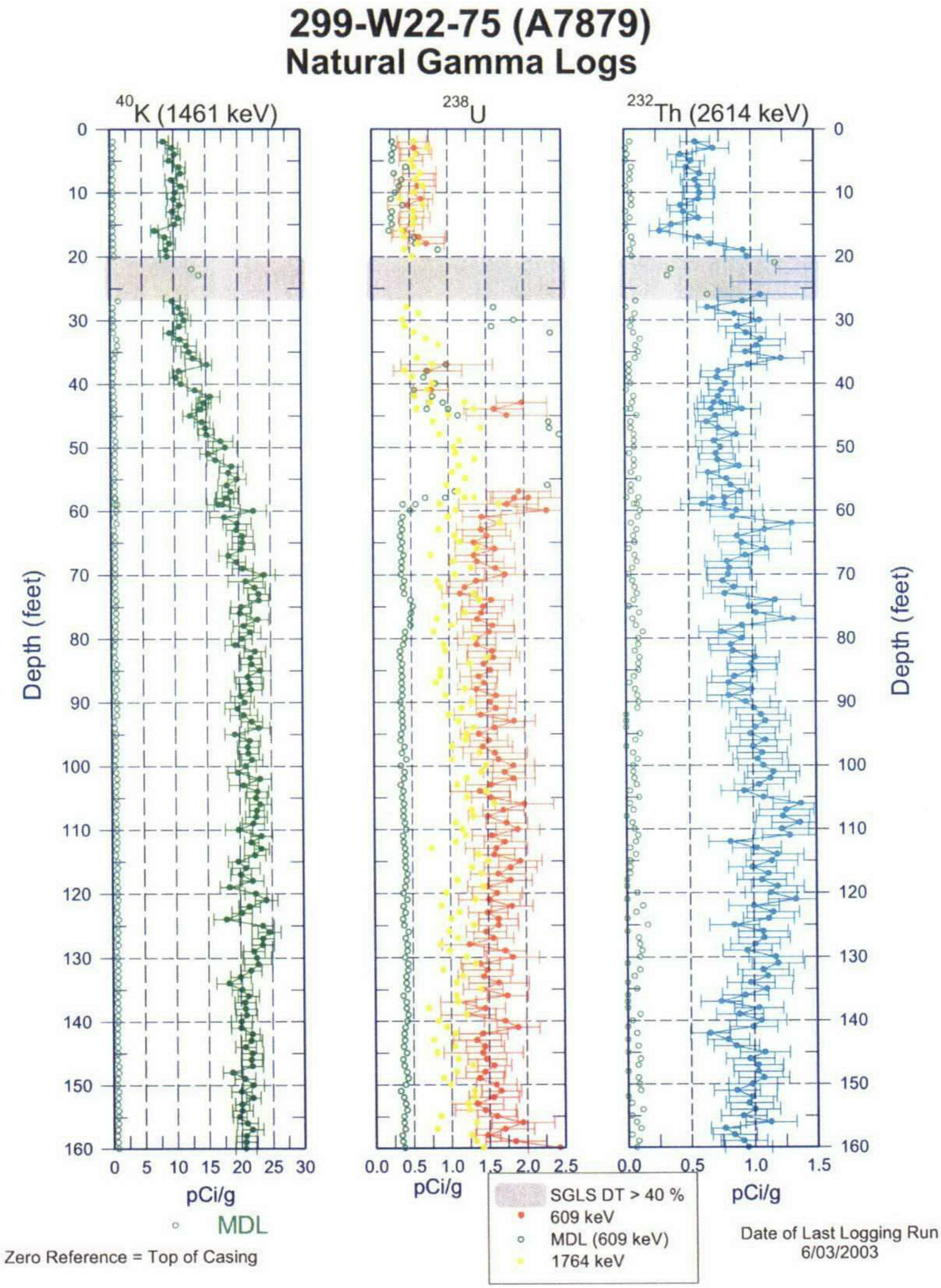
Date of Last Logging Run
6/03/2003

299-W22-75 (A7879)
Man-Made Radionuclides



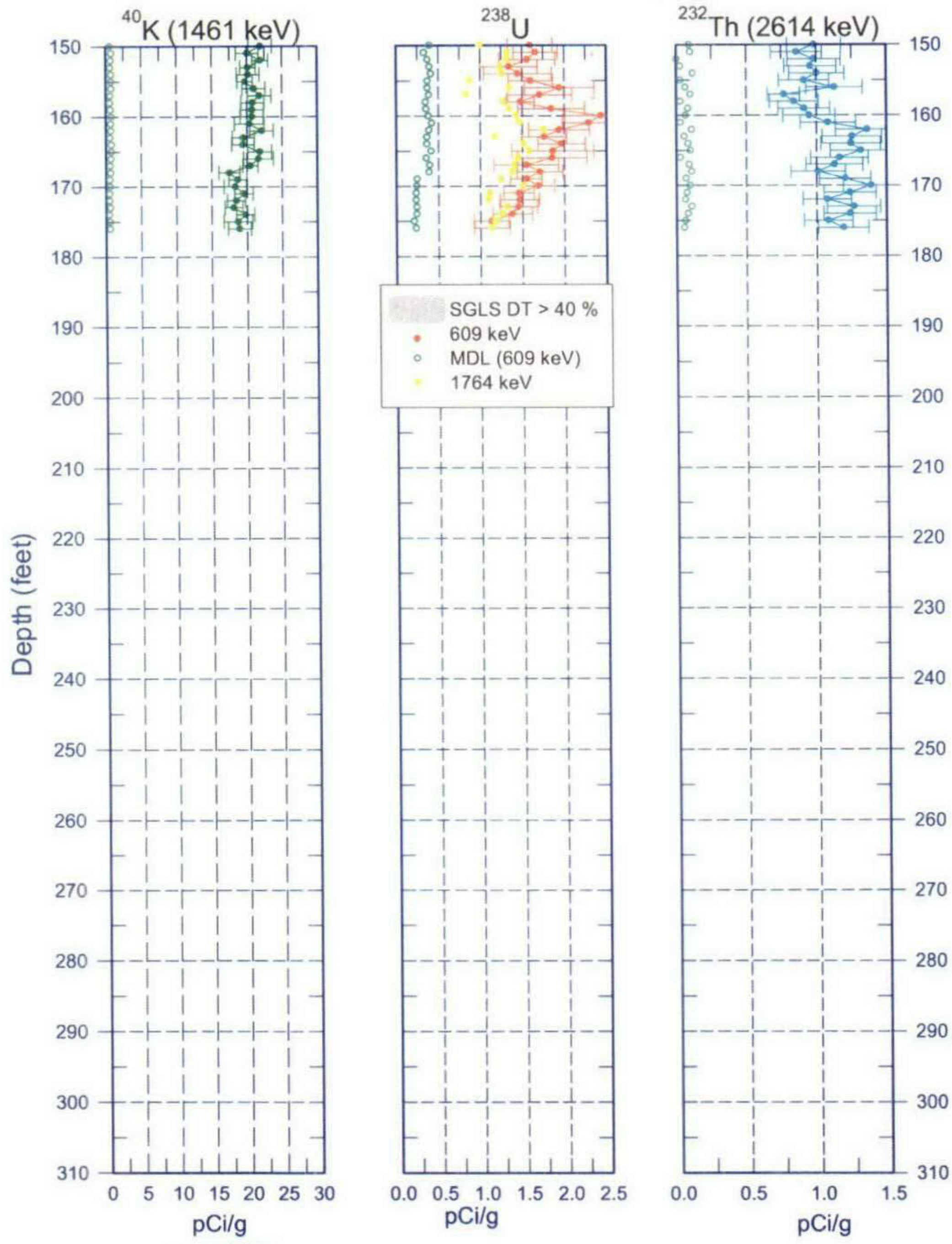
Zero Reference = Top of Casing

Date of Last Logging Run
6/03/2003



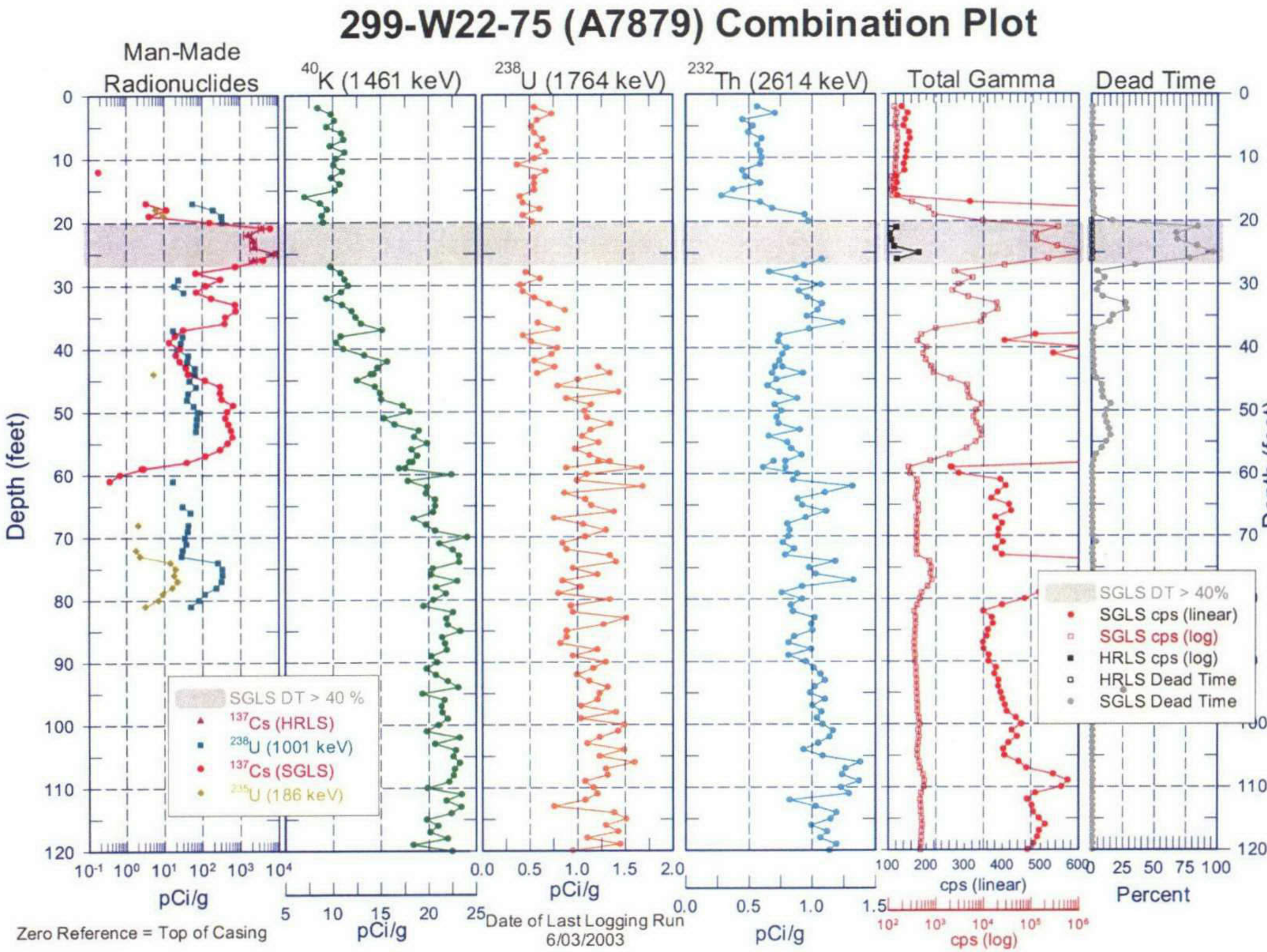
299-W22-75 (A7879)
Natural Gamma Logs
40K (1461 keV)
238U
232Th (2614 keV)
Depth (feet)
pCi/g
MDL
Zero Reference = Top of Casing
SGLS DT > 40 %
609 keV
MDL (609 keV)
1764 keV
Date of Last Logging Run
6/03/2003

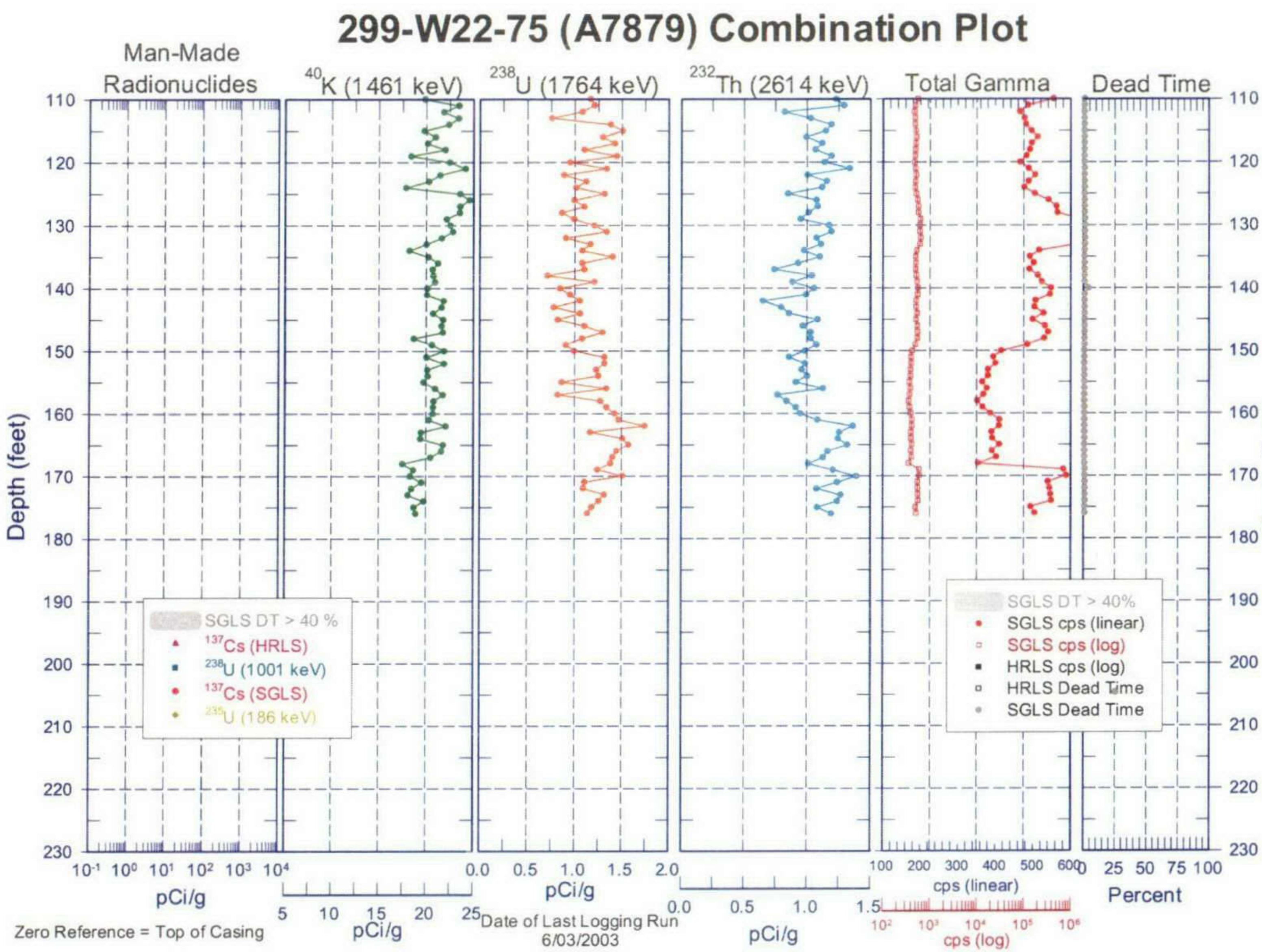
299-W22-75 (A7879)
Natural Gamma Logs



Zero Reference = Top of Casing

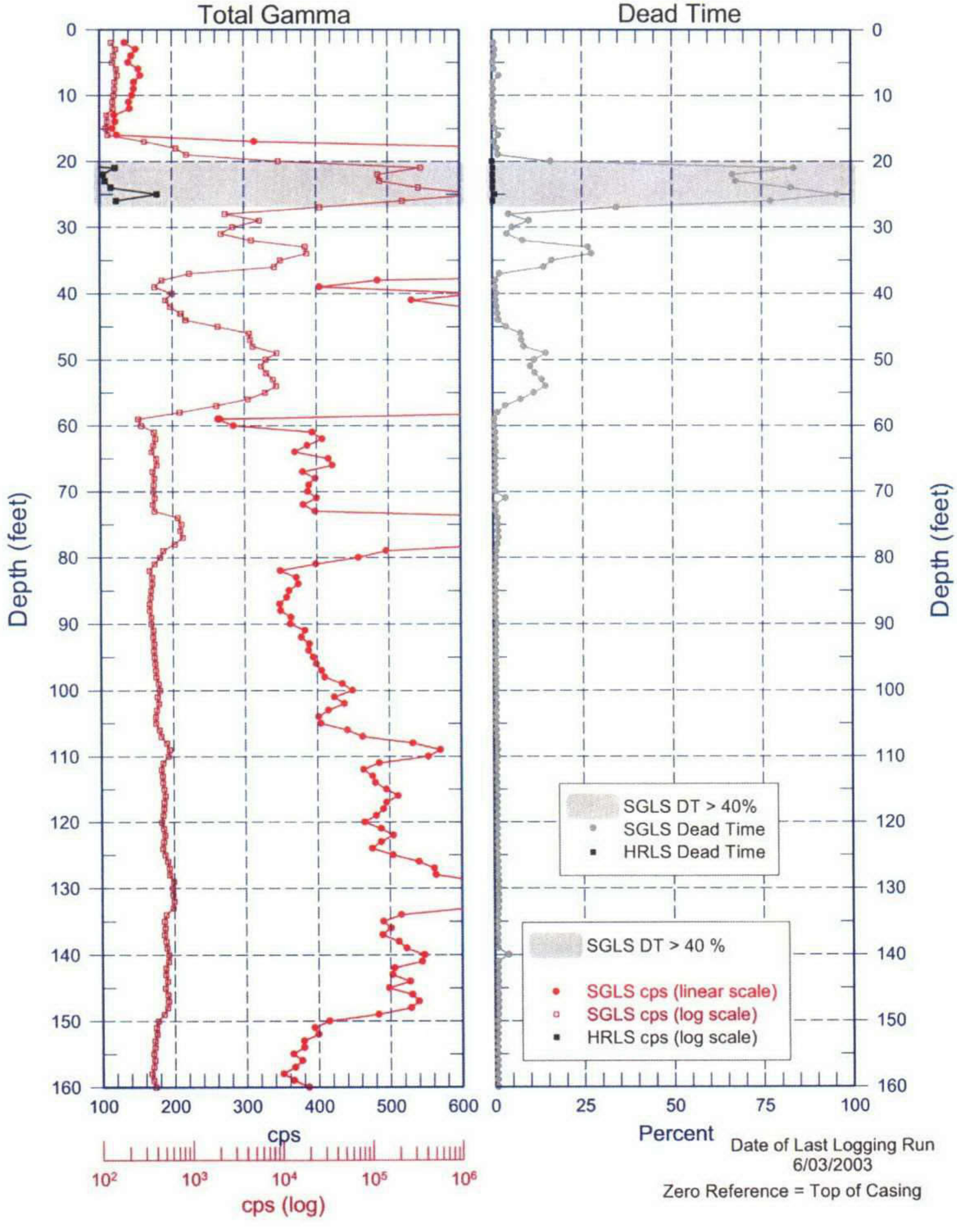
Date of Last Logging Run
6/03/2003

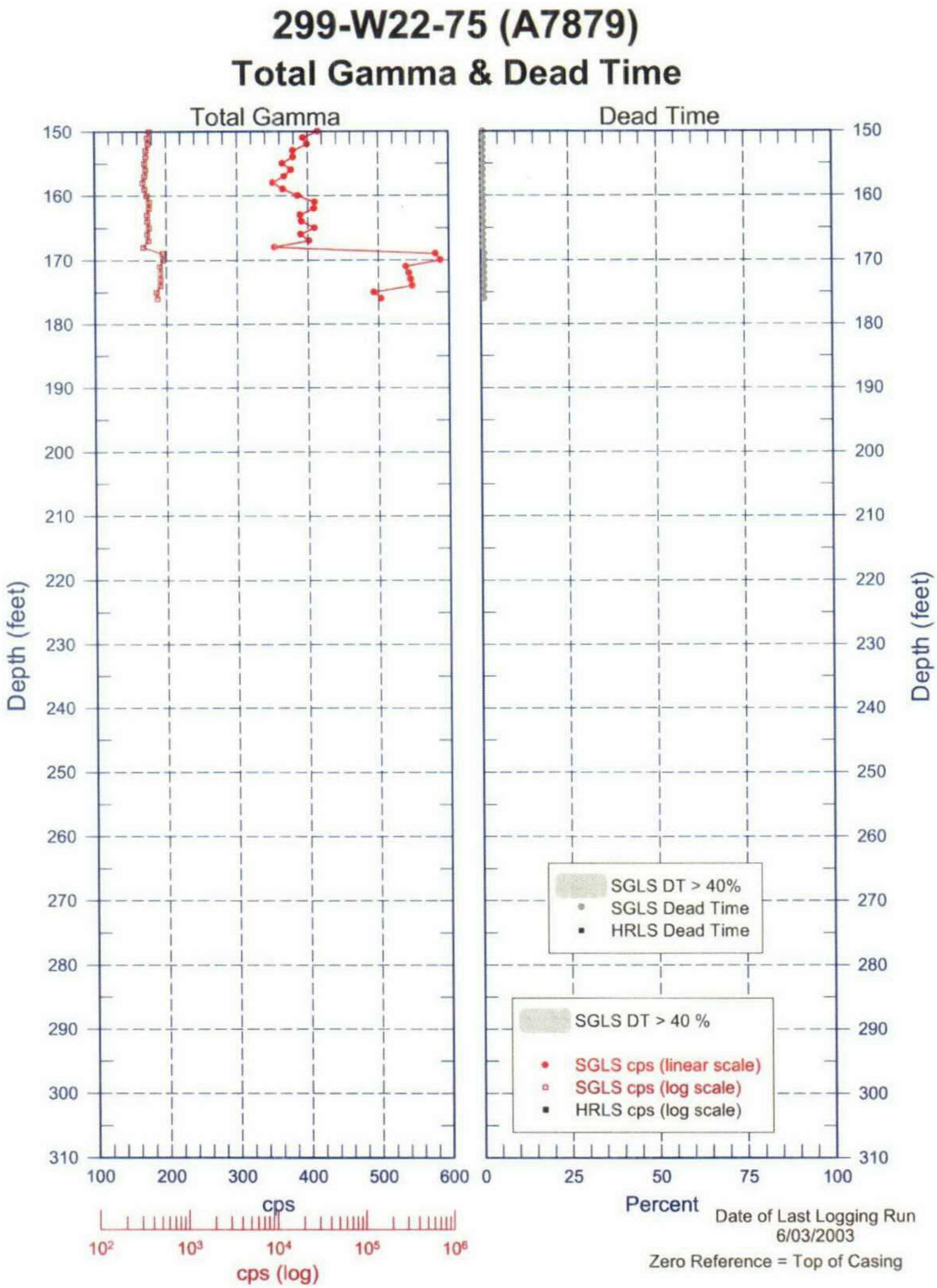

299-W22-75 (A7879) Combination Plot
Man-Made Radionuclides
40K (1461 keV)
238U (1764 keV)
232Th (2614 keV)
Total Gamma
Dead Time
Depth (feet)
pCi/g
cps (linear)
cps (log)
Percent
SGLS DT > 40 %
137Cs (HRLS)
238U (1001 keV)
137Cs (SGLS)
235U (186 keV)
SGLS DT > 40%
SGLS cps (linear)
SGLS cps (log)
HRLS cps (log)
HRLS Dead Time
SGLS Dead Time
Zero Reference = Top of Casing
Date of Last Logging Run
6/03/2003



299-W22-75 (A7879) Combination Plot
Man-Made Radionuclides
40K (1461 keV)
238U (1764 keV)
232Th (2614 keV)
Total Gamma
Dead Time
Depth (feet)
SGLS DT > 40 %
137Cs (HRLS)
238U (1001 keV)
137Cs (SGLS)
235U (186 keV)
SGLS DT > 40%
SGLS cps (linear)
SGLS cps (log)
HRLS cps (log)
HRLS Dead Time
SGLS Dead Time
pCi/g
cps (linear)
cps (log)
Percent
Zero Reference = Top of Casing
Date of Last Logging Run
6/03/2003

299-W22-75 (A7879)
Total Gamma & Dead Time

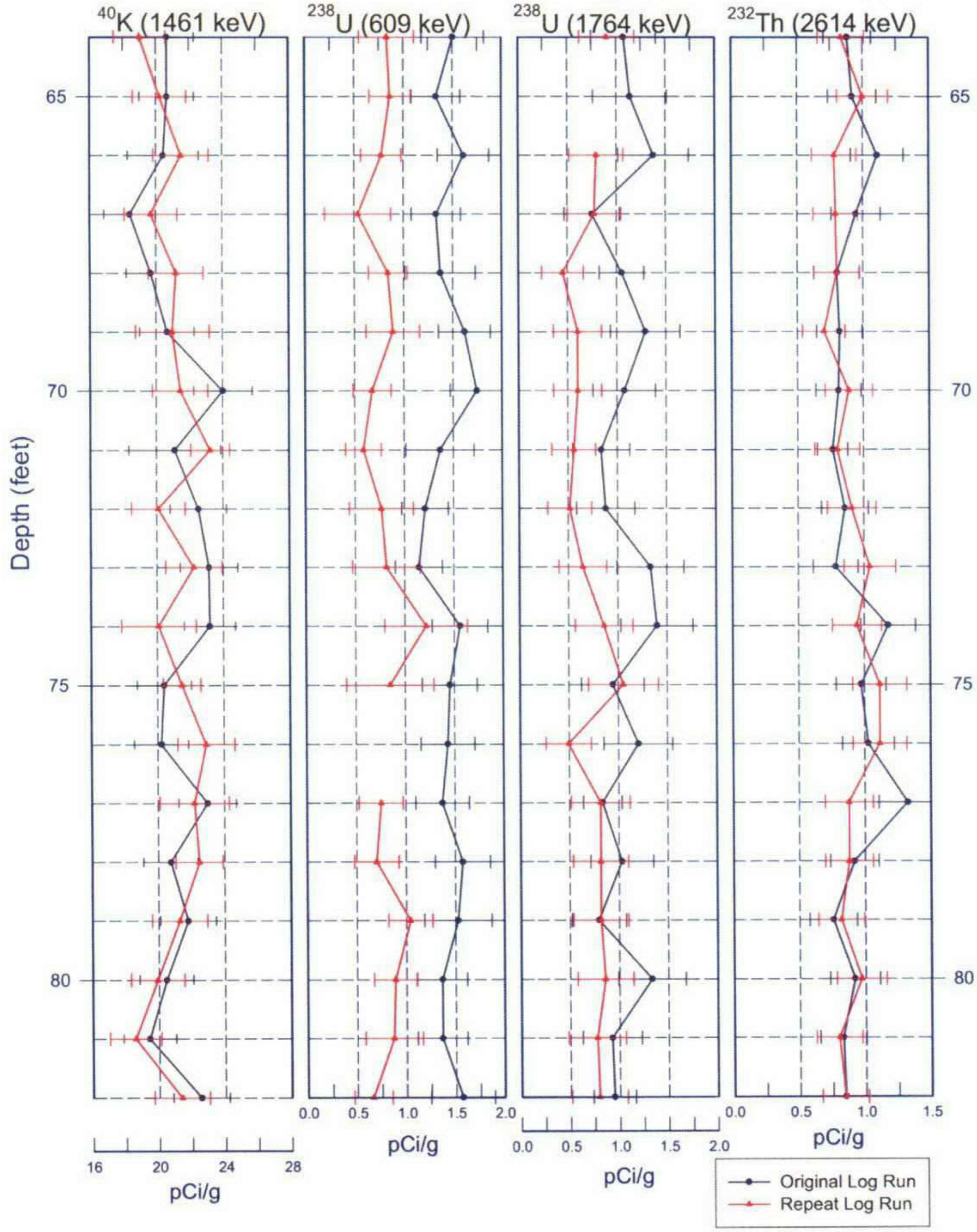


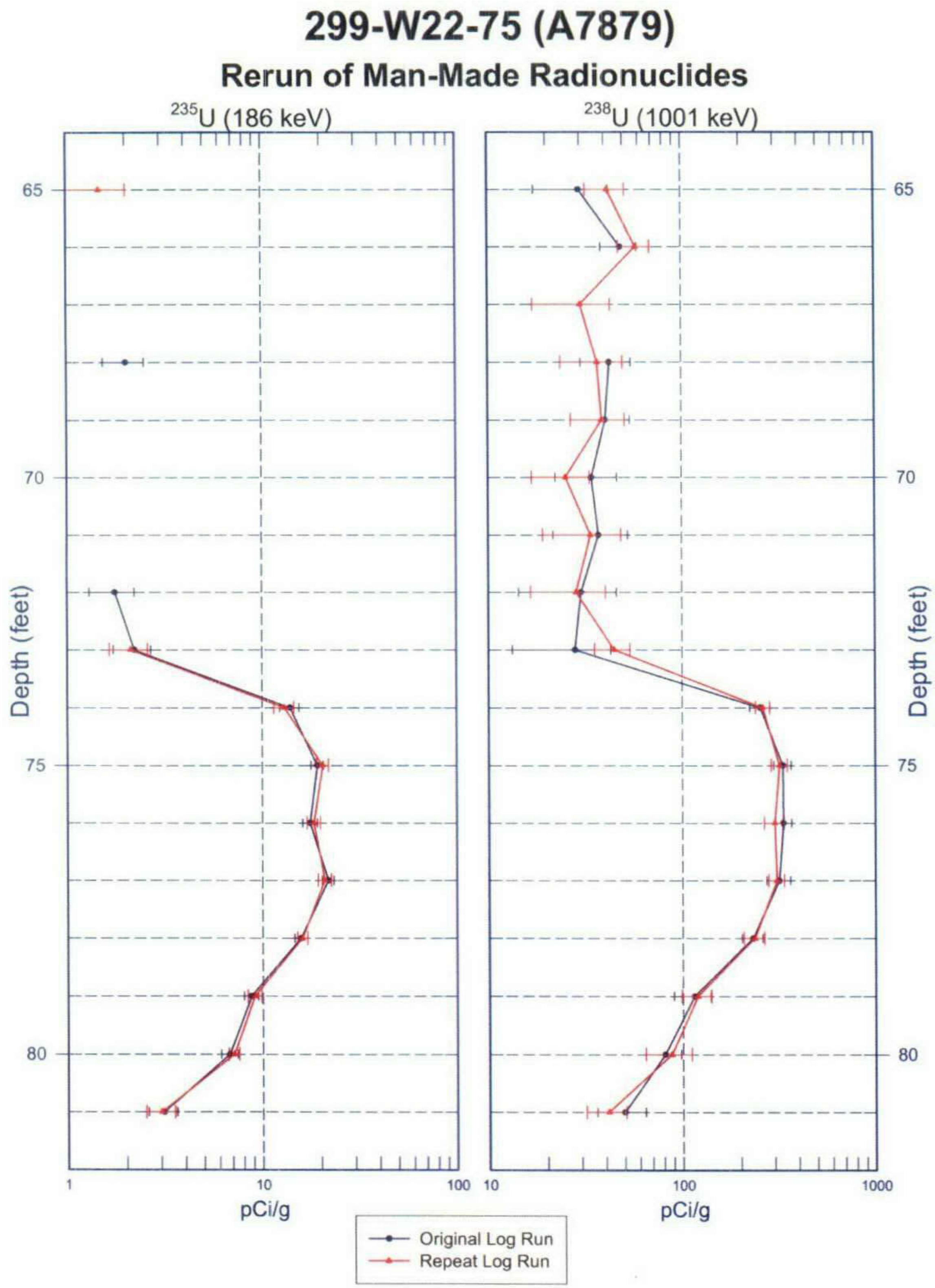


299-W22-75 (A7879)
Total Gamma & Dead Time
Total Gamma
Dead Time
Depth (feet)
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
100
200
300
400
500
600
cps
10^2
10^3
10^4
10^5
10^6
cps (log)
0
25
50
75
100
Percent
SGLS DT > 40%
SGLS Dead Time
HRLS Dead Time
SGLS DT > 40 %
SGLS cps (linear scale)
SGLS cps (log scale)
HRLS cps (log scale)
Date of Last Logging Run
6/03/2003
Zero Reference = Top of Casing

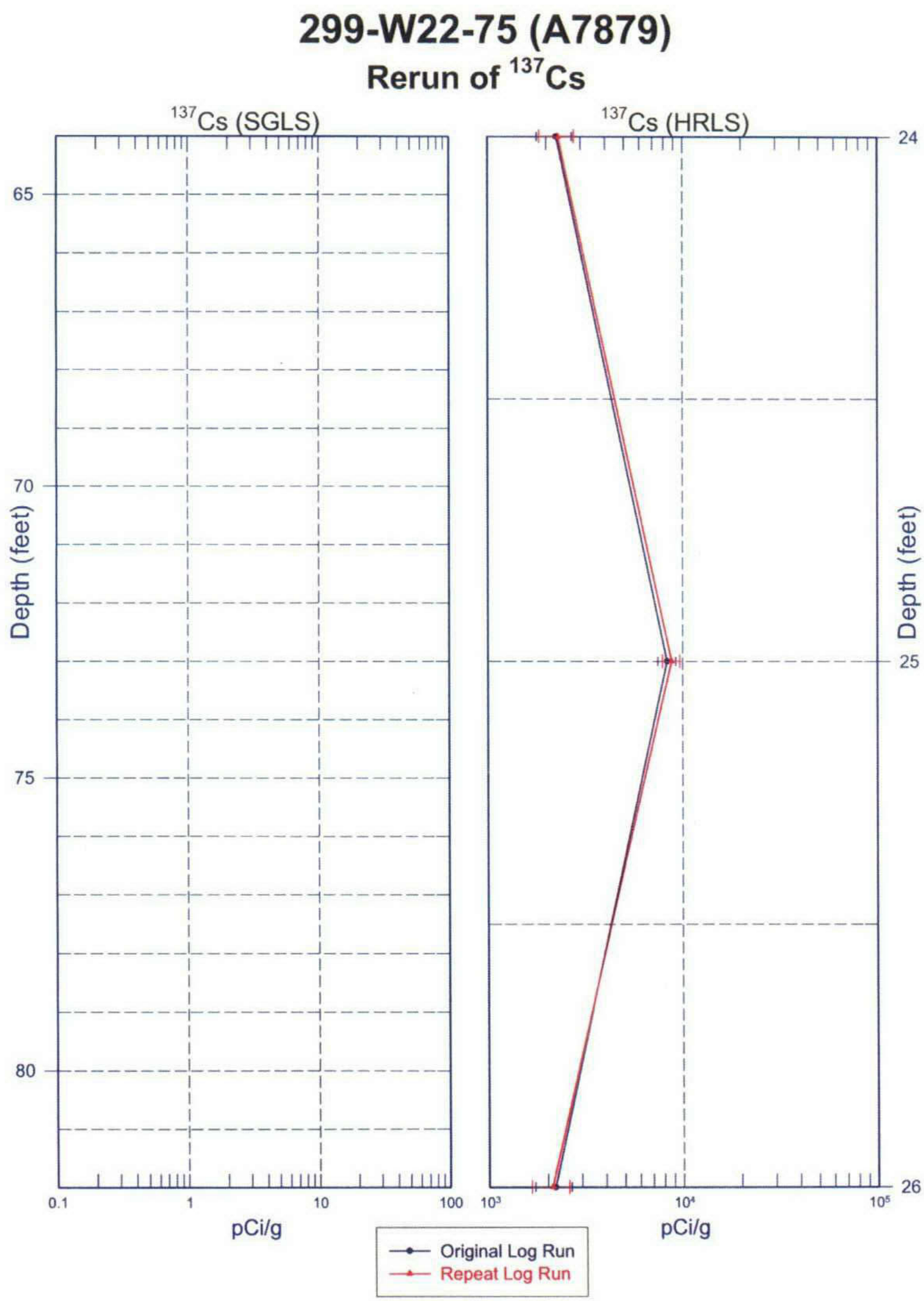
299-W22-75 (A7879)

Rerun of Natural Gamma Logs (82.0 to 64.0 ft)

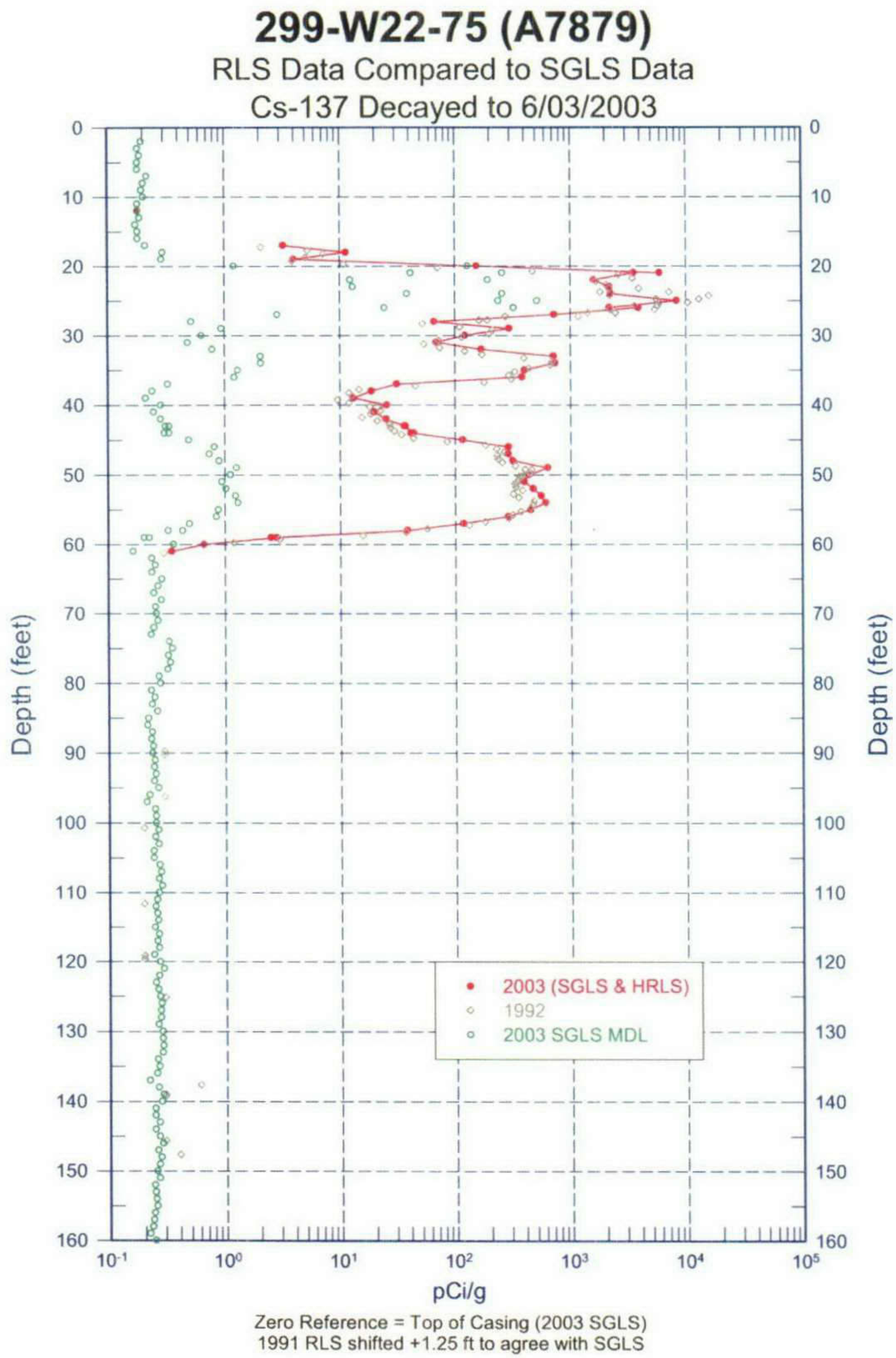




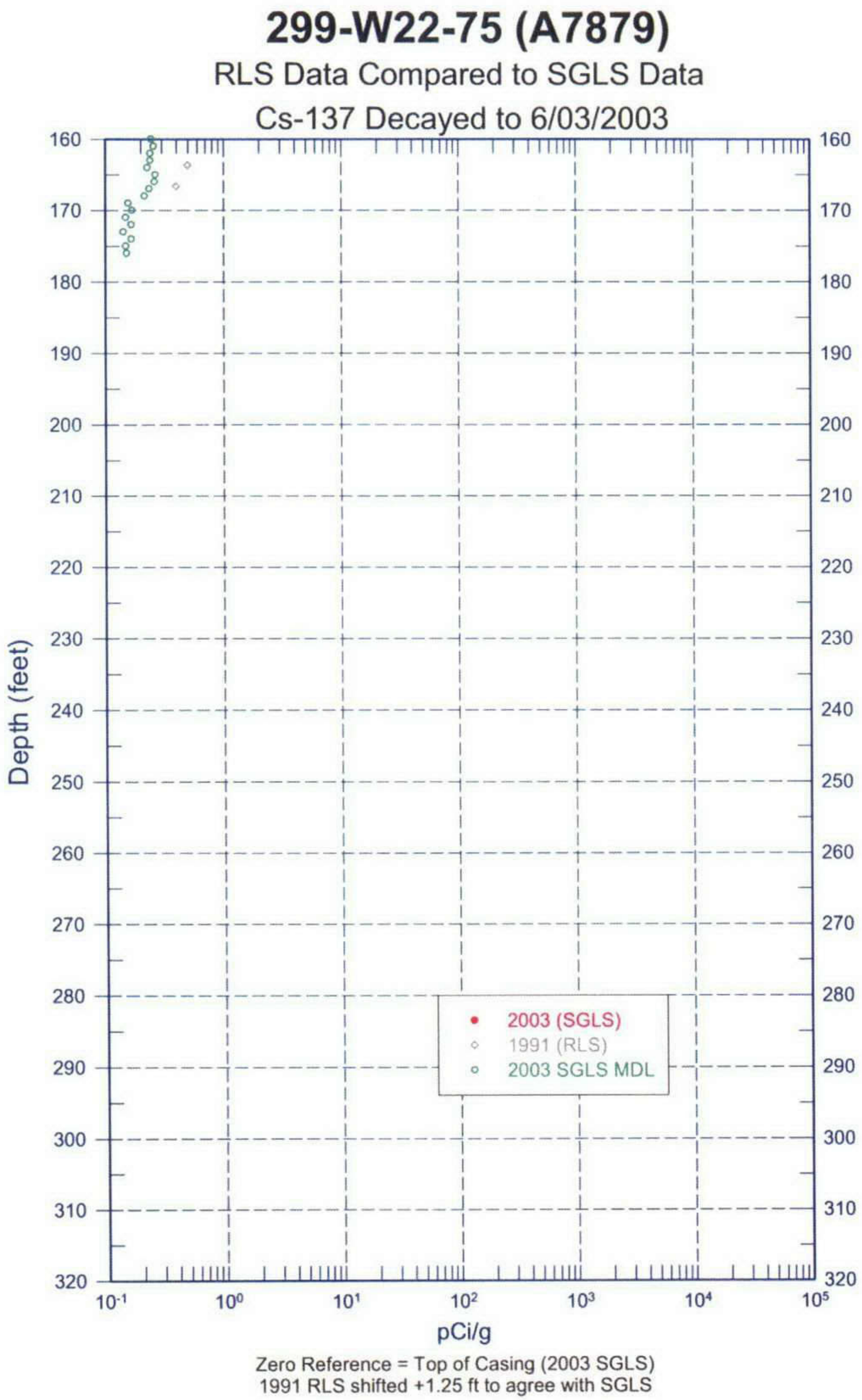
299-W22-75 (A7879)
Rerun of Man-Made Radionuclides
^{235}U (186 keV)
^{238}U (1001 keV)
Depth (feet)
65
70
75
80
1
10
100
1000
pCi/g
Original Log Run
Repeat Log Run

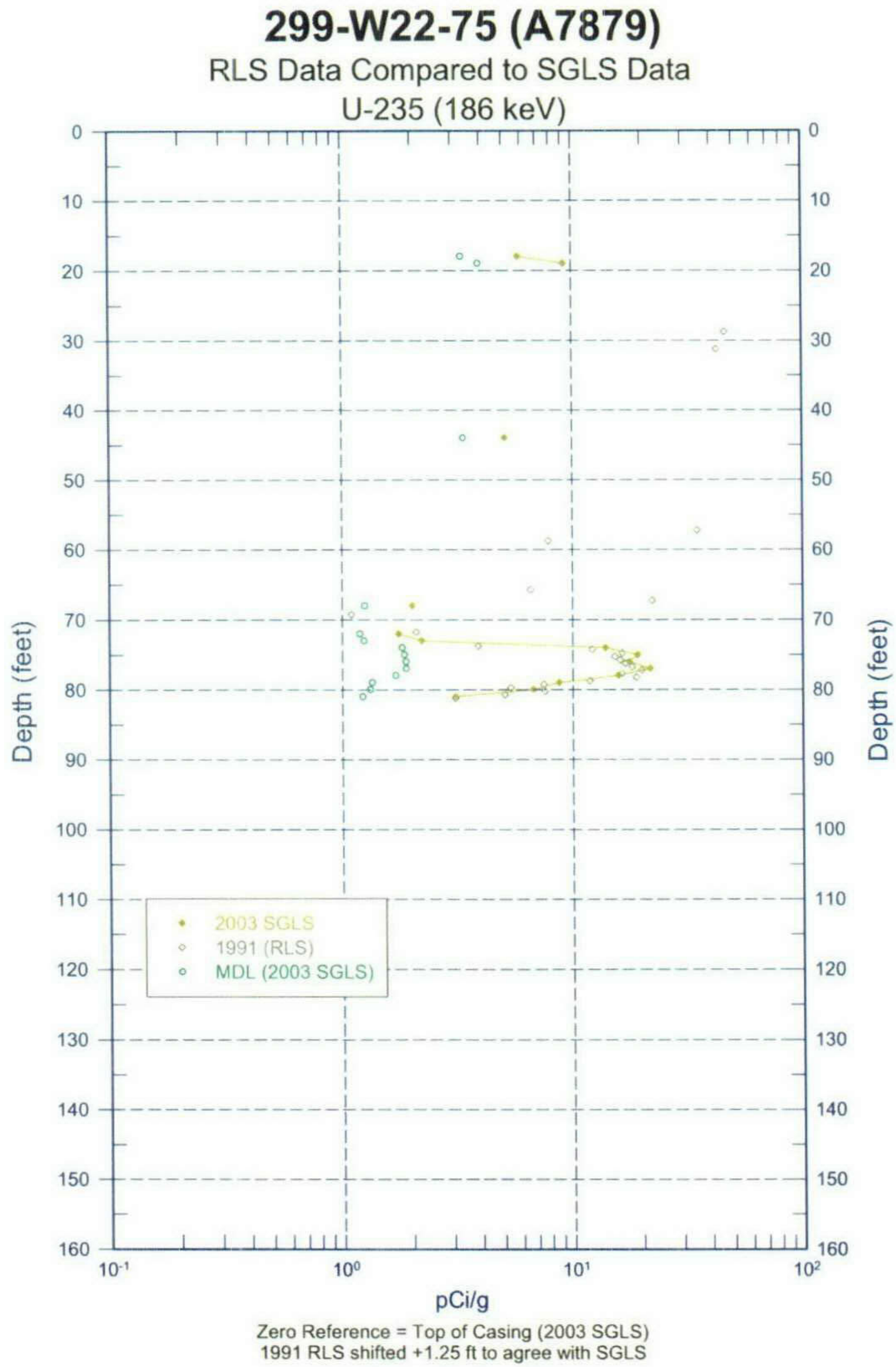


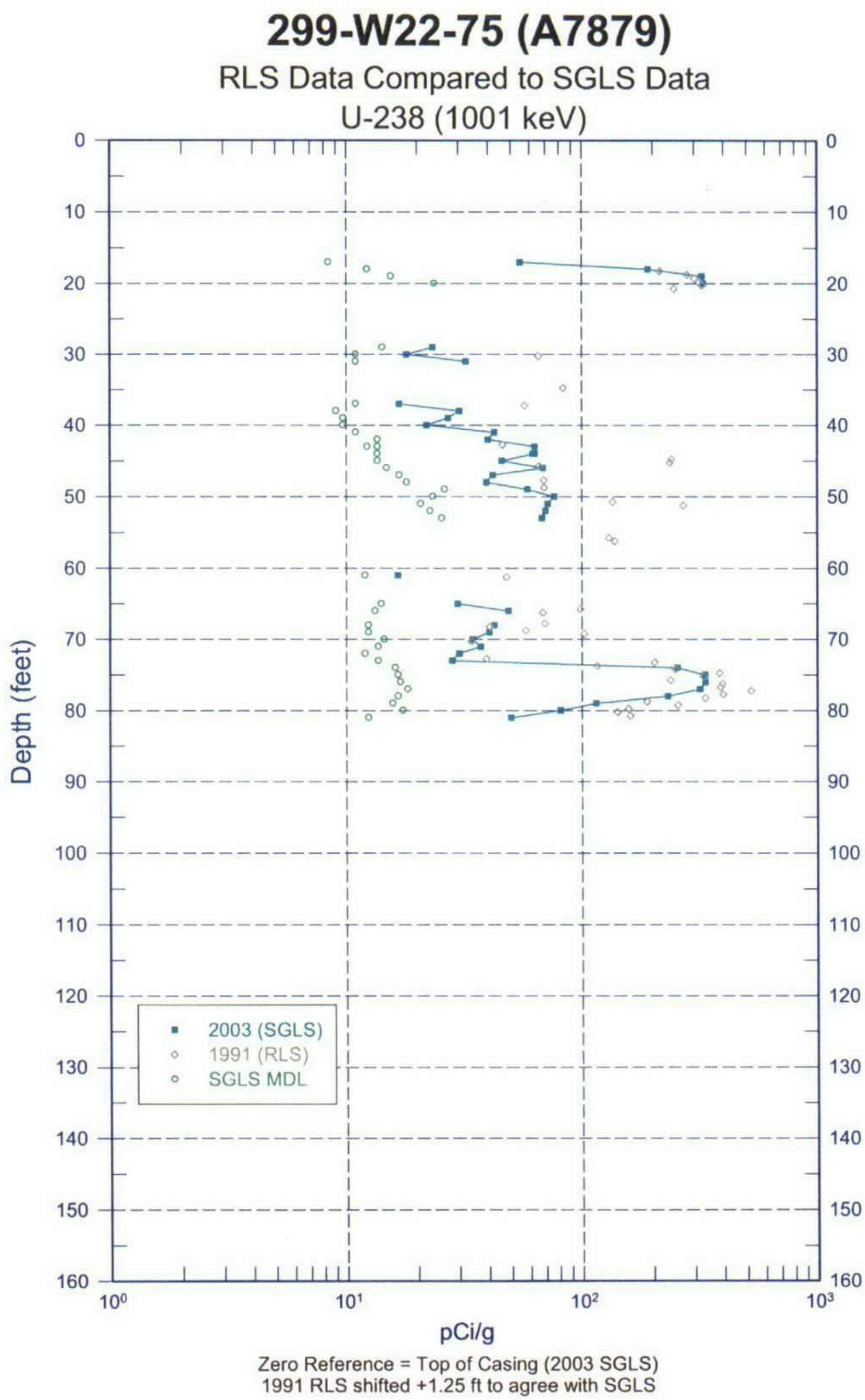
299-W22-75 (A7879)
Rerun of 137Cs
137Cs (SGLS)
137Cs (HRLS)
Depth (feet)
65
70
75
80
24
25
26
0.1
1
10
100
10³
10⁴
10⁵
pCi/g
Original Log Run
Repeat Log Run



299-W22-75 (A7879)
RLS Data Compared to SGLS Data
Cs-137 Decayed to 6/03/2003
Depth (feet)
pCi/g
2003 (SGLS & HRLS)
1992
2003 SGLS MDL
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS


299-W22-75 (A7879)
RLS Data Compared to SGLS Data
Cs-137 Decayed to 6/03/2003
Depth (feet)
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
pCi/g
2003 (SGLS)
1991 (RLS)
2003 SGLS MDL
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS


299-W22-75 (A7879)
RLS Data Compared to SGLS Data
U-235 (186 keV)
Depth (feet)
2003 SGLS
1991 (RLS)
MDL (2003 SGLS)
pCi/g
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS


299-W22-75 (A7879)
RLS Data Compared to SGLS Data
U-238 (1001 keV)
Depth (feet)
pCi/g
2003 (SGLS)
1991 (RLS)
SGLS MDL
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS

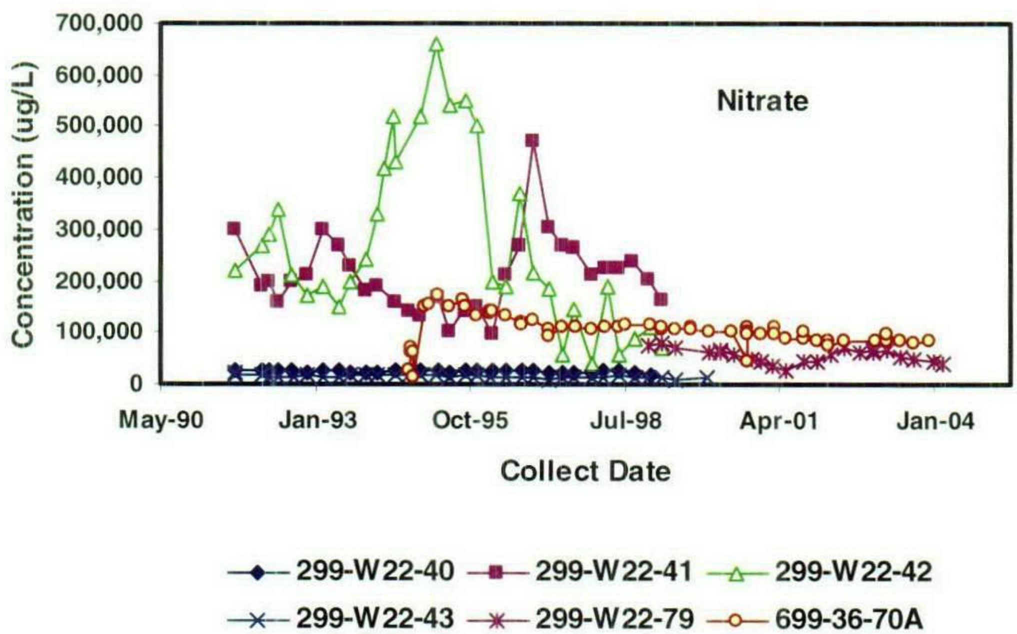
Appendix C

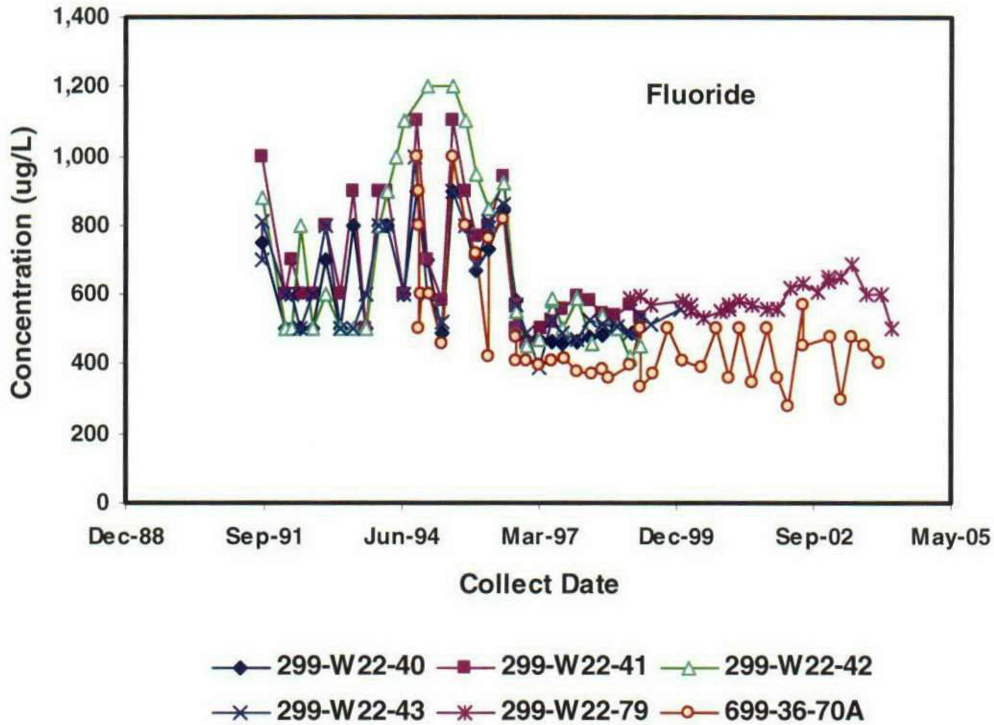
Groundwater Trend Plots of Selected Constituents at the 216-U-12 Crib

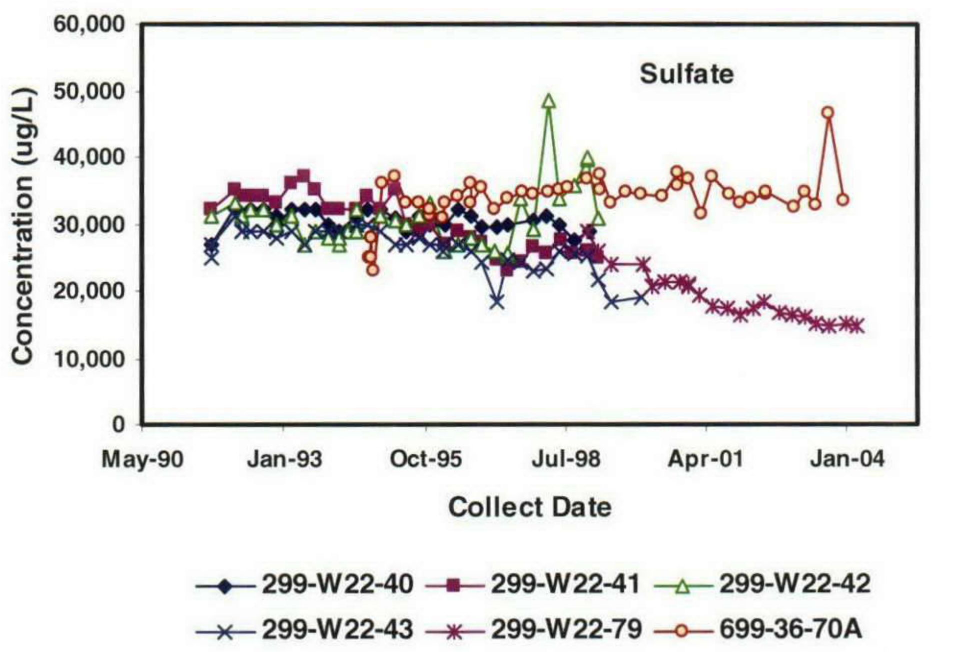
Appendix C

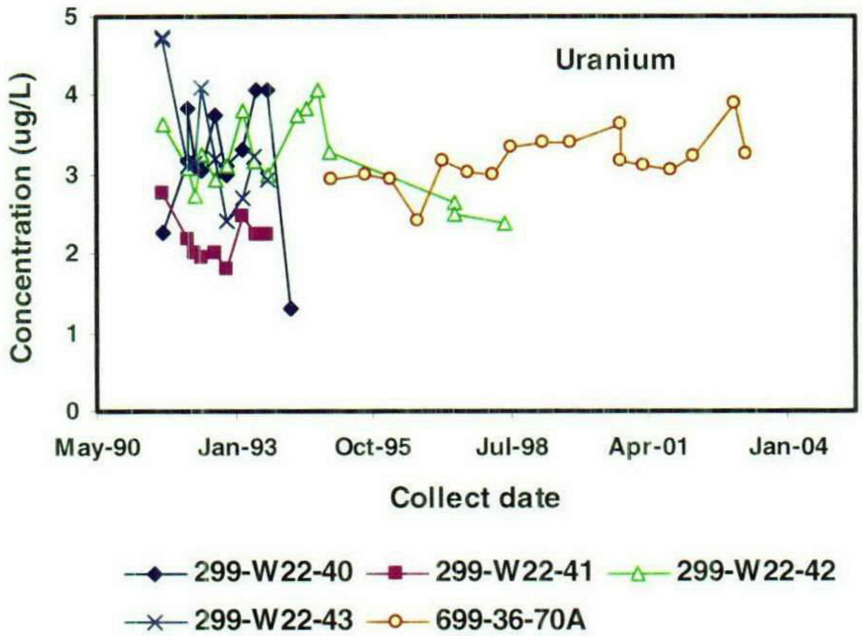
Groundwater Trend Plots of Selected Constituents at the 216-U-12 Crib

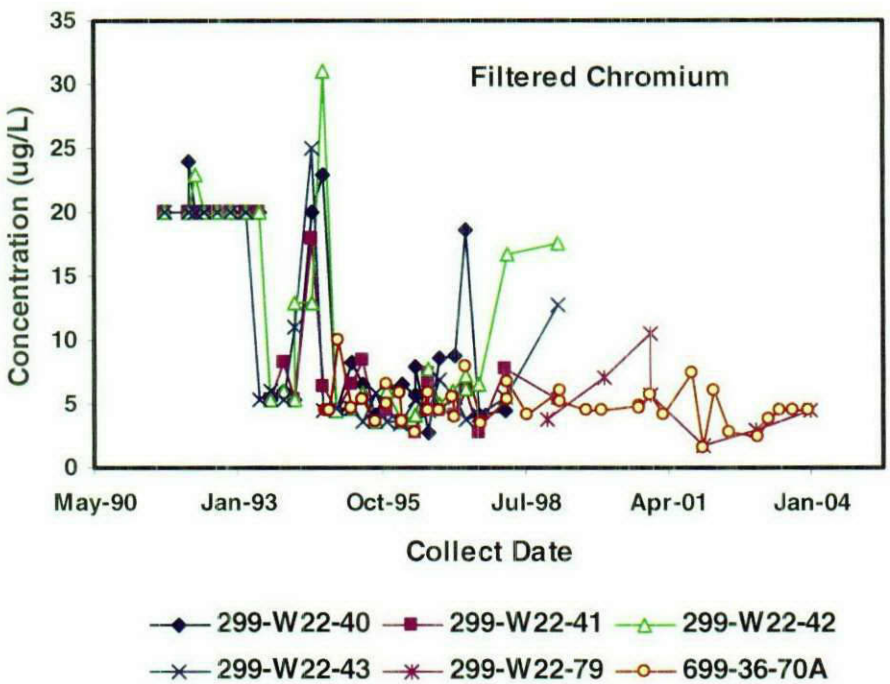
The trend plots in this appendix are for constituents that were listed in Table 1. It should be noted that: (1) for filtered chromium, analyses conducted during the period from September 1991to July 1993, the detection limit was 20 μg/L; (2) for filtered arsenic, analyses conducted during the period from September 1991 to March 1993, the detection limit was 5 μg/L; and (3) strontium-90 results were not plotted because all of the analyses were non-detects.

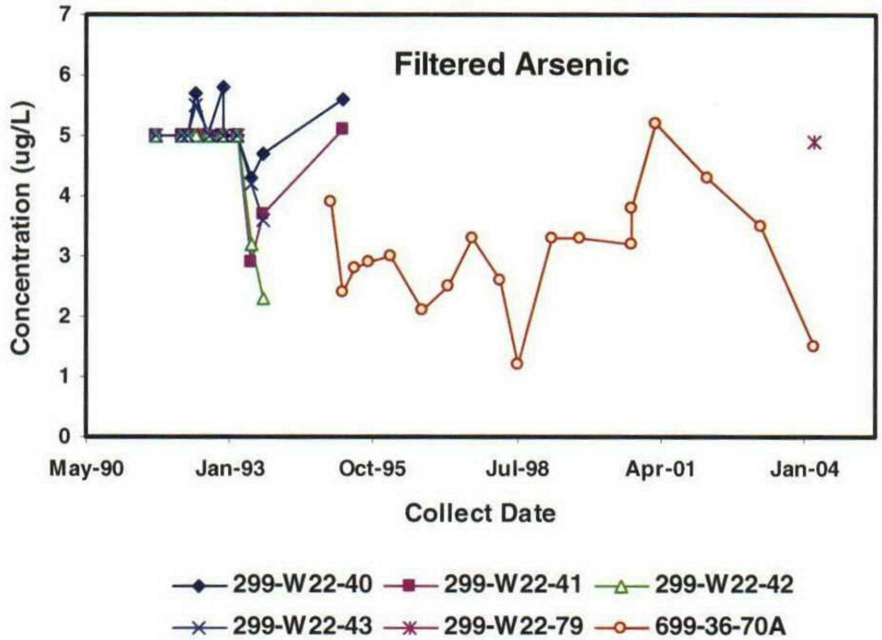



Fluoride
Concentration (ug/L)
1,400
1,200
1,000
800
600
400
200
0
Dec-88
Sep-91
Jun-94
Mar-97
Dec-99
Sep-02
May-05
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A

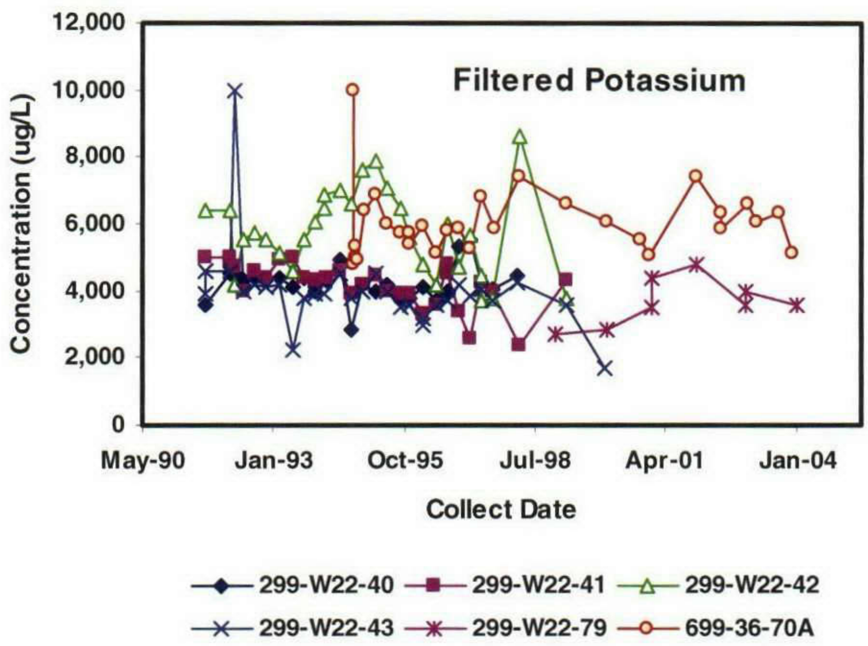

Sulfate
Concentration (ug/L)
60,000
50,000
40,000
30,000
20,000
10,000
0
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A


Uranium
Concentration (ug/L)
0
1
2
3
4
5
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Collect date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
699-36-70A

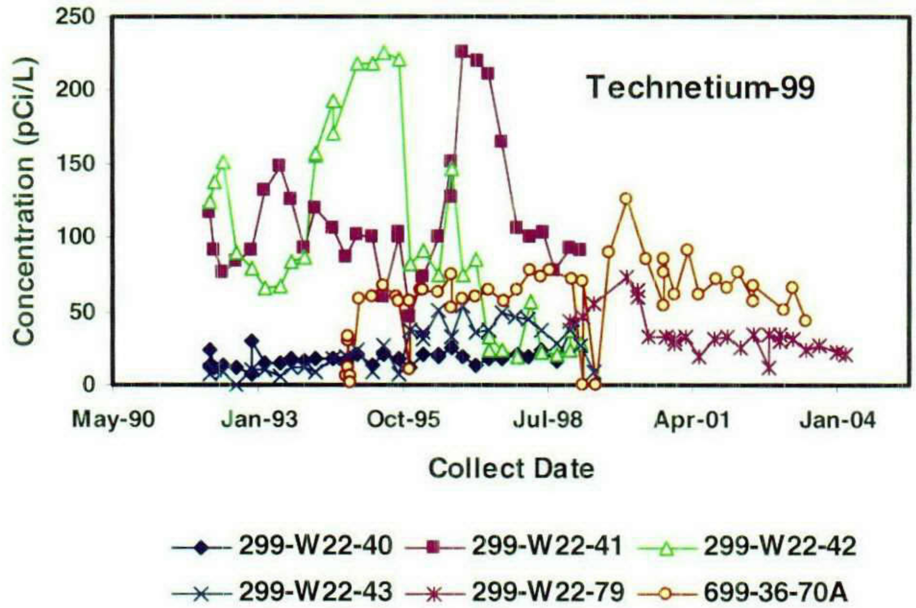

Filtered Chromium
Concentration (ug/L)
0
5
10
15
20
25
30
35
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A

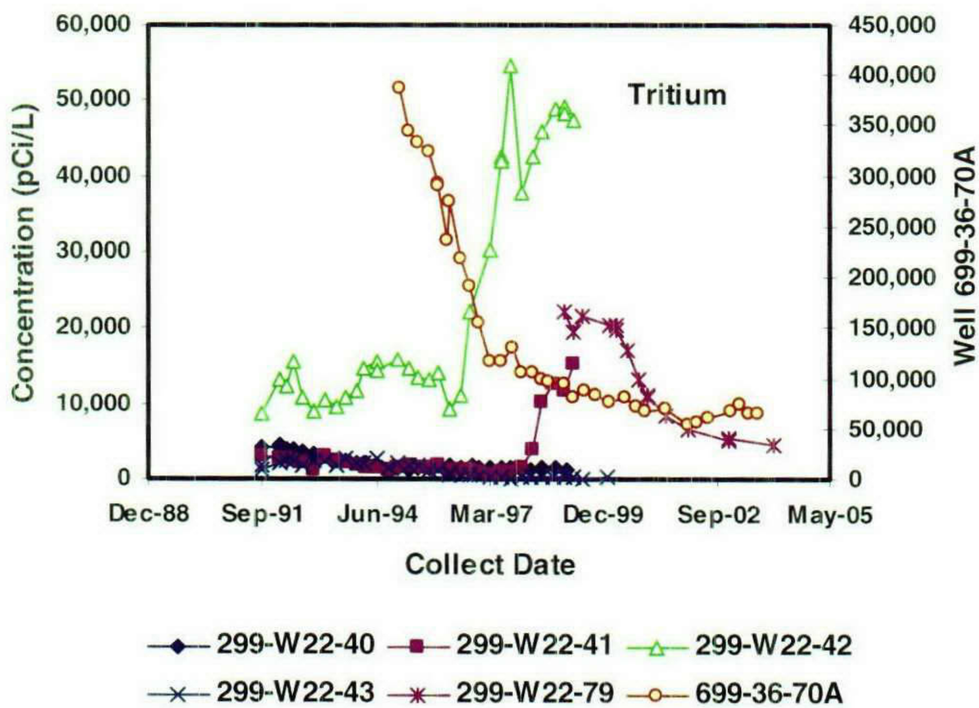


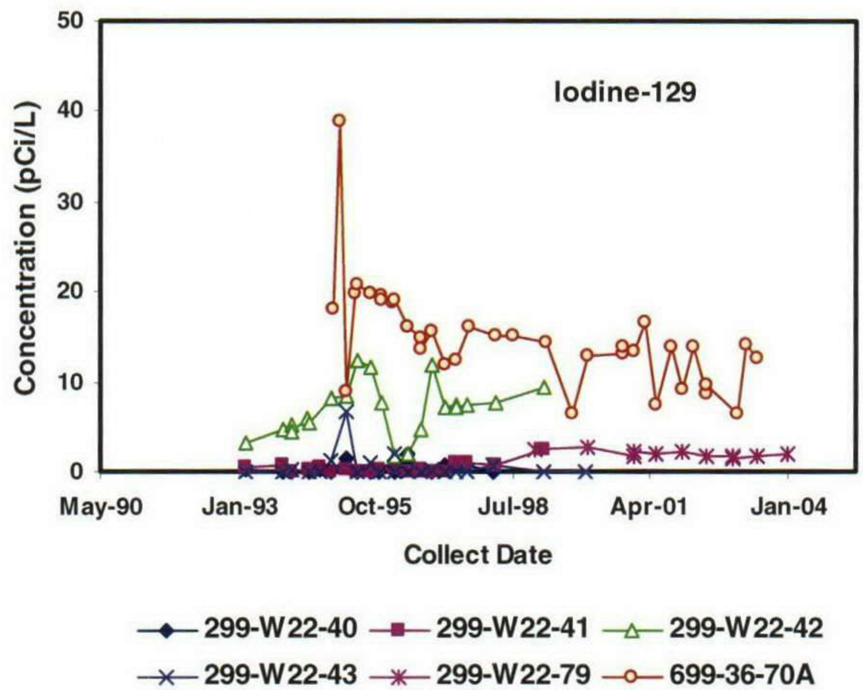
Filtered Arsenic
Concentration (ug/L)
Collect Date
0
1
2
3
4
5
6
7
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A

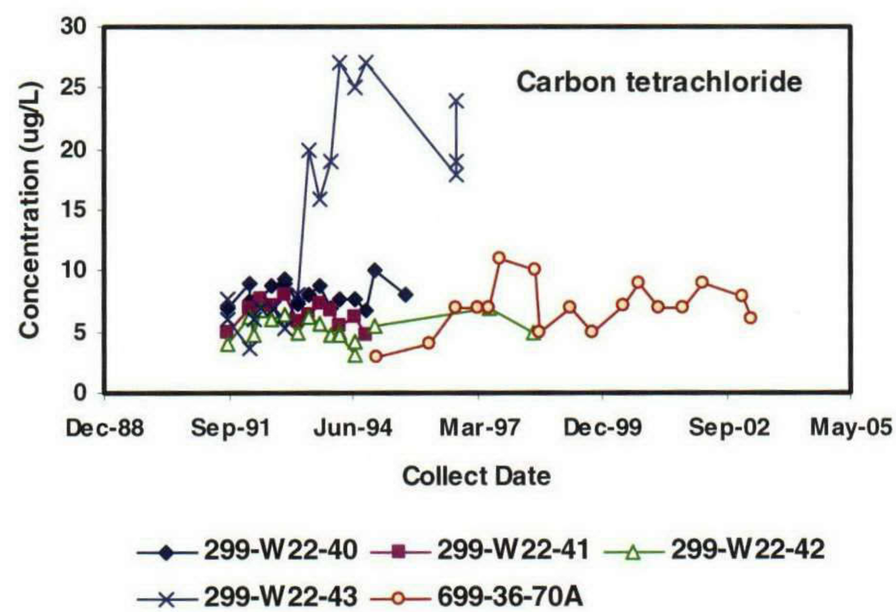


Filtered Potassium
Concentration (ug/L)
Collect Date
0
2,000
4,000
6,000
8,000
10,000
12,000
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A


Technetium-99
Concentration (pCi/L)
250
200
150
100
50
0
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A


Tritium
Concentration (pCi/L)
60,000
50,000
40,000
30,000
20,000
10,000
0
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Well 699-36-70A
Dec-88
Sep-91
Jun-94
Mar-97
Dec-99
Sep-02
May-05
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A


Iodine-129
Concentration (pCi/L)
50
40
30
20
10
0
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
299-W22-79
699-36-70A


Carbon tetrachloride
Concentration (ug/L)
30
25
20
15
10
5
0
Dec-88
Sep-91
Jun-94
Mar-97
Dec-99
Sep-02
May-05
Collect Date
299-W22-40
299-W22-41
299-W22-42
299-W22-43
699-36-70A